

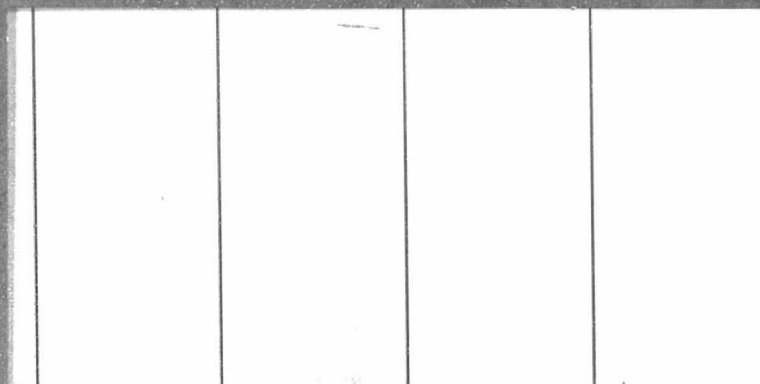
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SECOND QUARTERLY REPORT  
LANDSAT II INVESTIGATION PROGRAM  
NO. 28230

REPORT NO. 531

JUNE 1976

Principal Investigator:

Dr Mervyn C. Probine

Co-Investigators:

Dr Richard P. Suggate

Mr Ian F. Stirling

Mr Michael G. McGreevy

**ORIGINAL CONTAINS  
COLOR ILLUSTRATIONS**

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I believe that this second quarterly report shows that very good progress is being made in the development of techniques for using Remote Sensing technology as a useful tool in several areas of national importance. These include the use of CCT data to identify forest blow-down areas in the Eyrewell State Forest; the use of colour composites designed to assist the location and tracing of geological faulting; the use of imagery for hill shading and map correction; the assessment of forest resources; and the spread of disease in forests.

In addition to the use of already developed techniques for studies of the kind outlined above, very encouraging developments have been under way on the development of image enhancement and clustering techniques using computer methods. Some of the results obtained are very impressive in spite of the limitations of our plotting equipment. There has also been a very marked improvement in the quality of our colour composites.

Once again I have to express our thanks to our friends in NASA - and particularly to Dr Robert Price - for continued excellent service and co-operation. I feel, however, that in spite of our gratitude for the help we have received, I must draw attention to a matter which is of some concern to us; namely, the very long time lag between the acquisition of an image by the satellite and the arrival of CCT's in New Zealand. A reduction in this time interval would greatly increase the effectiveness of our program. I hope that it will be possible to make some improvement in this particular service.

As I said earlier, I think that it will be apparent to all who read this latest report that the N.Z. project team (the group in DSIR, and the three co-investigators and their groups) is making very good progress. Some very valuable material is beginning to become available from the project, and I have no doubt that some even more important developments can be expected in the near future.



Dr Mervyn C. Probine

Principal Investigator

21 June 1976



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                              IN NEW ZEALAND
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                              IN NEW ZEALAND
- PART III                   INDIGENOUS FOREST ASSESSMENT
- PART IV                   SEISMOTECTONIC, STRUCTURAL, VOLCANOLOGIC  
                              AND GEOMORPHIC STUDY OF NEW ZEALAND

DEVELOPMENT OF REMOTE SENSING  
-TECHNOLOGY IN NEW ZEALAND

Investigation No.: 28230

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Remote Sensing Section Report: - RS 76/06

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## 1. INTRODUCTION

The first report was largely devoted to a description of the developing facilities in the PEL remote sensing section, to its interaction with co-investigators and other "user" groups in New Zealand, and to outlining its current programme.

This time we wish to present a limited number of topics in more depth. The preceding three months have seen developments in two areas of CCT processing, in the production of photographic products more appropriate to the Co-investigators' needs, and in a better understanding of the problems of image registration.

The investigation of forest blow-down areas in mid-Canterbury was prompted by a request from the N.Z. Forest Service, who are concerned to see if the conditions of blown down timber can be detected on LANDSAT imagery, in order to determine priorities in their milling programme. The results so far, given in sections 2.6.2 and 3.2, show that blow-down areas can be detected in the imagery. Determination of the condition of these areas is, however, inconclusive, and work continues to explore the limits of information contained in the data. The illustrations given are colour composites derived from the electrostatic lineprinter and the poor quality of these products tend to mask the real worth of the computer enhancement techniques used to produce them. Eventually it is hoped to acquire a photowrite machine, possibly during the next financial year.

Development of our CCT processing has been speeded by the arrival of the first two LANDSAT II CCT's. A two pronged approach is under way at present. One of us (ILT) is using the large computer facilities in Wellington (IBM 370/168) via a terminal at PEL, to develop re-formatting and interpretative programs of a type which should eventually form the basis of a national, user interactive network. This work gives us experience in formulating and developing a large system.

Another of our section (MMcD) is using the smaller PEL in-house facilities to develop more fundamental concepts of image processing, including enhancement and clustering techniques on images subsequently displayed by photographic

means. This work is concerned with the treatment of relatively small areas on a 128 x 128 pixel matrix. The results, however, can be transferred and expanded on a large computer. The successful development of these programs has led to a decision to treat our multispectral aircraft imagery in the same way, and our microdensitometer is being upgraded to an automatic raster scanning device to convert the images to CCT form.

Registration of imagery for production of colour composites has always been a problem and an investigation has been started (PJE, ADF) to improve this situation by re-alignment of the additive viewer, and to increase our understanding of the sources of error. (Section 2.1.)

## 2. TECHNIQUES

### 2.1 Photographic Processing

#### 2.1.1 Analysis of Registration Errors

Colour composite prints and transparencies have now been produced in the PEL facility for about two years. During this period, difficulties have been experienced in obtaining satisfactory spatial registration of individual band transparencies, from both LANDSAT photographic products and from PEL aircraft multispectral negatives.

The problem arises from (a) the quality of the products being registered; and (b) from distortions introduced within the colour compositing equipment. The quality of the aircraft product is discussed in section 2.2. In this section, we report on a programme of error analysis, started during this reporting period, and aimed at reducing errors in our LANDSAT colour composites.

Two methods of producing colour composites are currently in use. The first and most operationally convenient method utilises the I<sup>2</sup>s "Mini Addcol" colour additive viewer, in which 1:1000000 scale prints and transparencies are produced by direct exposure. The second is described in our first report (PEL 508). 1:1000000 scale monochrome transparencies are used in a contact process in which the pre-punch registered images are successively contacted with the colour material,

and exposed to a red, green and blue filtered light source. This method was developed to overcome registration problems due to the colour additive viewer.

Even with the contact method, however, registration with certain scenes has been unacceptably poor. The colour composite transparencies permit the production of enlarged prints which in turn place a more stringent requirement on the initial registration. For interpretative work involving direct viewing, the additive viewer has proved to be entirely adequate. These problems have prompted us to investigate the sources of error in detail. The results reported here are incomplete, and further work is planned for the next reporting period.

#### 2.1.1.1 Registration Requirements

The 70 mm photographic product utilises a scan line length (cross track) of 55 mm, with a nominal in-track image size of 53 mm. The number of picture elements (pixels) in the cross track direction is typically 3240 and in the in-track direction there are 2256 scan lines. This gives a pixel size on the negative of 0.017 mm x 0.023 mm. corresponding to a ground field of view of 57 x 79 m.

It follows that there are approximately 59 pixels per mm in the cross track direction and 43 per mm in the in-track direction. The Data Users Handbook (ERTS-1) gives the modulation transfer function (MTF) for the 70 mm third generation film material, and indicates that the modulation depth has fallen to 70% of its maximum value at a spatial frequency of about 50 cycles/mm.

The film characteristics, together with the modulation transfer function of the scanner itself, will introduce "adjacency" effects between pixels, particularly in the cross track direction, which degrades the spatial resolution and reduces the necessity for precise registration to within small fractions of a pixel.

Evaluation of enlarged colour composites has indicated that registration errors are detectable on the image if the misalignment exceeds about 0.02 mm on the transparency. This is most easily apparent as colour fringing at the fiducial marks, which have a measured line width of 0.05 mm.

### 2.1.1.2 Error Investigation and Alignment of the Colour Additive Viewer

Experiments with duplicated images of a test grid showed that misregistration errors of up to 0.4 mm were occurring on the screen of the colour additive viewer. The schematic arrangement of the "Mini-Addcol" viewer is shown in Figure 1(a). Registration of the images on the viewing screen is achieved by translational adjustments of the individual projection lenses, and by rotation of the 70 mm transparencies in the carrier. The large mirror should be adjusted until the viewing screen is optically parallel to the transparency carrier. Small changes of scale are possible by screwing individual lenses along the axis normal to the transparency plane. The overall magnification is set to 3.369, giving a 1:1000000 scale image on the viewing screen. A vacuum back, containing colour film or print material, replaces the screen when making colour composites.

Initially, the original plate glass mirror was replaced by a much thicker, optically plane, front aluminised mirror produced in the PEL optics section. The projection lenses were also checked for distortion by this section. Tests so far show that misregistration errors due to lens distortion are negligibly small. It is planned to conduct more accurate tests using a new optical system recently acquired by the optics section.

The major contribution to misregistration error was shown to be the incorrect alignment of the plane surfaces in the instrument. For correct operation, it is essential that the transparencies are optically parallel to the viewing screen. Rotation of a transparency about an axis parallel to its plane has the effect of producing trapezium distortion in the image. The effect of rotation on the magnified image can be estimated by considering the effect on its extremities. In the case of LANDSAT images, these extremities can be regarded as the fiducial marks.

Let  $\theta$  = the maximum angle between the normal to the transparency plane, and an extreme ray joining a fiducial mark with the nodal point of the lens.



We assume that a small rotation of the transparency from the plane parallel position, about an axis lying in the transparency plane, produces a displacement  $\delta Z$  of the fiducial mark in the direction of the normal to the plane (Z-axis).

Then the maximum displacement  $\delta r$  of the image of the fiducial mark in the viewing plane is, to a good approximation

$$\delta r = M \delta Z \tan(\theta) \quad (1)$$

where M is the instrument magnification.

Taking into account the lateral displacement of the lens in the colour additive viewer, the maximum angular displacement of a fiducial mark from the Z-axis is  $17.2^\circ$ . This means that a Z displacement of the fiducial mark of 0.1 mm, will result in a shift of 0.1 mm of its image in the viewing screen.

The nature of the off-axis optical system means that fiducial marks on the same image will have different angular displacements from the Z-axis.

#### 2.1.1.3 Alignment

By angular adjustment of the mirror, it is possible to make the plane of the transparency carrier and of the viewing screen optically parallel. Great difficulty has been experienced in the past in achieving this alignment. This has now been made much easier with the small ray projector shown in the simplified diagram of Figure 1(b). With the lenses removed from the viewer, the projector is mounted on the rear of the viewing screen. The transparencies are replaced with non-reflecting black paper, and the projected ray is reflected from the surfaces of the bottom glass of the transparency holder. An image of the aperture-plate is focussed through a hole on the projector mount on to the viewing screen. The attitude of the projector can be adjusted by screws forming two of the three kinematic supporting feet.

If the carrier and screen are optically parallel, rotation of the projector mount will not affect the relative positions of the focussed ray and the hole in the mount. By iterative adjustment of the mirror angular position and the projector attitude, it is possible to align the surfaces to a high accuracy in a short time. The total path length of the ray is 1700 mm, giving a ray displacement of 0.99 mm for a rotational error of one arc minute. This rotational error, about an image centre, corresponds to a maximum fiducial mark displacement of 0.041 mm on the viewing screen.

When first used, the projector produced two displaced images on the screen for three out of the four transparency holders. These images, displaced by as much as 2.5 mm, indicated that the front and back surfaces of the transparency holder-glass were not parallel. Subsequent measurements showed thickness variations across the glass of more than 0.05 mm. An unfavourable combination of glasses would cause apparent misregistration errors of 0.007 mm at the 1:3,369,000 scale, i.e., just over one third of a pixel. The optics section is now producing a set of optically parallel replacement glasses.

The projector also showed that the four transparency holders were not plane parallel. The transparency carrier itself became slightly distorted when inserted into the machine and this alone introduces a considerable rotational error. Each transparency holder is aligned after manufacture, by adjustment of three support screws. These have now been replaced by socket head screws, enabling each holder to be individually aligned in situ. Small distortions in the transparencies themselves can also be corrected in this way (see section 2.1.1.4).

The re-aligned system, with lenses set to give a magnification of 3.369, showed an improvement of about a factor of five over previous work. Figure 3, of the central North Island region, is an example of a print produced directly on the improved system.

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#### 2.1.1.4 Spatial Distortion of 70 mm Photographic Products

Image distortion on the 70 mm transparencies can, in certain cases, be reduced by careful alignment of the holders in the additive viewer. This does, however, increase the complexity of colour compositing considerably.

Figure 2 shows the disposition of the image and fiducial marks on the LANDSAT II 70 mm negative. In this reporting period, careful measurements of four scenes have been made. We propose to extend these measurements to cover the majority of scenes so far received. The fiducial marks are intended to assist in image registration, and our experience indicates that correlation between fiducial mark registration and image registration is excellent. However, the fiducial marks depart from the positions postulated by the rectangular set given in the Data Users Handbook, and these positions vary between scenes and between bands.

The results of the four sets of measurements are given in Table 1. A description of the method of measurement follows. All measurements were made on a "Tri-Optic" measuring machine, manufactured by S.I.P. Geneva, and housed in the PEL Metrology section. This machine operates in a temperature and humidity controlled environment ( $20^{\circ}\text{C} \pm 1^{\circ}\text{C}$  and 60% RH). Scale resolution is 0.00005" and interpolation can be made to 0.00001". All co-ordinates refer to the centres of the fiducial marks. The negatives are mounted on an illuminated plane table, and kept flat with a cover glass previously checked for flatness and thickness variations. Repeatability of measurements has been estimated by making multiple checks of twelve fiducial mark separations, over a period of days. The rms error was found to be 0.00005" or 0.0013 mm.

Figure 2 shows the co-ordinate system, in which all co-ordinates are referred to fiducial mark F1 as the origin, and defining the X-axis as the line passing through F1 and F4.

Examination of the data shows that the fiducial mark separation in the in-track (Y) direction is always greater than the nominal dimension of 59.5 mm, with a maximum discrepancy of 0.874 mm (1.46%), and a minimum of 0.451 mm.

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A check of image scale by the Department of Lands & Survey confirms that the images are elongated in proportion to the observed discrepancies. The data also shows that the four sided figure with corners defined by the fiducial marks is not always a rectangle. These deviations vary from band to band within the same scene. Misregistration due to these effects can sometimes be partially compensated by adjustments to each individual negative carrier plane in the additive viewer.

Future measurements will indicate the extent to which these discrepancies can be compensated by a set of simple rotational transformations introduced, for instance, during the compositing process. It is hoped eventually to use the computer to analyse any distortions in either the photographic products or in the colour compositing apparatus, in order to predict the degree and type of transformations required for correction.

#### 2.1.2 Products for Co-investigators

During this reporting period, the NZ Geological Survey has been using the colour additive viewer to determine a more optimum form of colour composite for their interpretative purposes. The result has been the combination of positive and negative transparencies, bands 4 and 7, illustrated and described in part IV of this report.

#### 2.2 Aircraft Program

In the last report, we mentioned the difficulties of image registration using an unmatched set of 80 mm lenses in our Hasselblad multispectral camera/radiometer. A matched set of 100 mm planar lenses has recently arrived, and preliminary flight trials were conducted in May. The results have not yet been fully evaluated, but a first examination of the negatives indicates that the dependence of focal length on wavelength for each band may have been over-compensated, resulting in small scale-differences with the lenses focussed at infinity.

Those trials were the first in which the camera alignments were checked using the ray projector described in section 2.1.1.3. If the film planes of each camera are not

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plane parallel, the result is trapezium distortion and misregistration of the type experienced in the colour additive viewer. The ray projector was mounted on a flat base directly underneath the downward viewing camera, suspended at a height of 2m above the base. With lenses and backs removed, small front silvered mirrors were mounted on the reference surface forming the back of the camera body. Alignment to an accuracy of better than 25 arc-seconds is then achieved using the procedure described in section 2.1.1.3.

Aerial coverage of the Darfield test site is temporarily suspended due to unavailability of aircraft during the winter months. This is not a serious problem, since we now have seasonal coverage for a one year period. An intensive evaluation of these results is now required in order to formulate the continuous program.

Analysis of the aircraft imagery, and comparison with the satellite product, has been hampered by the necessity to make individual measurements on a manually operated micro-densitometer. The steps being taken to improve this situation are discussed in section 2.11.

### 2.3 Ground Truth

The ground truth data which we gathered on 2 August and 31 October 1975, for farms in the Darfield area, coincided with aerial and satellite coverage. This ground truth data is at present being correlated with the corresponding CCT's to determine the extent to which differing crop types can be distinguished. Preliminary results of this investigation are reported in section 2.6.

Factors such as: solar elevation angle, cloud induced "bright spots", ground moisture, soil type, fertiliser or spraying effects, wind pressure, animal grazing characteristics, etc; can cause variations in a spectral signature nominally allocated to a given target.

In section 2.7 we indicate how we currently determine the "typical" spectral signature for our desired targets. Influences such as those indicated above can render these "typical" spectral signatures less applicable to other areas in the same scene and increasingly less applicable between scenes.

We are conscious of our need to compare both our method of determining this typical spectral signature and our understanding of the magnitude of other influences upon this signature. Effort is being directed to this question and it will probably be quite a protracted study, involving ground truth measurements with the field spectrometer under development.

#### 2.4 Atmospheric Measurements

The atmospheric extinction program described in section 2.4 of our first report is continuing. A report and paper on this activity is planned as a joint exercise with Dr M.J. Duggin of CSIRO, Australia. Dr Duggin's visit to PEL has, however, been delayed until August, and it is hoped to include this work in the next quarterly report.

#### 2.5 Scanning Microdensitometer

The section has a "Gamma" microdensitometer which is primarily used in the analysis of aircraft photographic transparencies. The unit has already been extensively modified with the inclusion of an image locating table in which pre-punch-registered transparencies can be located according to an accurate co-ordinate system. Co-ordinate position indicators have been added to both the X and Y scan.

It is now planned to improve the system to give an automatic digital output to paper tape when operating in a raster scanning mode. The raster scan is switchable between unit cell sizes of 0.1 mm, 0.5 mm and 1 mm, forming a square matrix. Use of the 0.5 mm interval allows a 55 mm square image to be digitised to fit within the 128 x 128 matrix already used (section 3.1) to develop programs for analysing LANDSAT CCT's. In this way, the aircraft imagery can be analysed using the same programs as for the LANDSAT scenes.

The mechanical scan drive system is now complete. The original X-scan d.c. motor drives via a modified gear to give a maximum line speed of 4 mm per second, and a stepper motor added to the Y scan provides the Y-increment at the end of each line. An optical pickoff on the scanning stage provides a trigger pulse to the data logger. The photo-multiplier has been replaced with a PIN diode detector to give greater stability and a rapid response.

The system, when working, should permit one image to be digitised on a 0.5 mm matrix in about 36 minutes. For a standard aircraft image, scaled at 1:63,360, the linear spatial resolution is approximately 2.5times better than the present LANDSAT CCT imagery.

#### 2.6.1 Reformatting of Computer Compatible Tapes

As discussed in our first quarterly report (PEL 508), the CCT reformatting is being developed on the IBM 370/168 machine using the PL/1 language.

The basic decoding and write-to-disc storage sections are operational for small areas (low volume data extents). Current attention is directed towards extending the size of the data base that can be operated upon, using disc packs attached to central storage. Not only will this facilitate the reformatting but will also greatly aid future cartographic correction manipulations.

We intend to produce two basic formats each having the whole scene written on a line by line basis (incorporating all four strips):

- (i) on a pixel by pixel basis generating one complete scene for each band;
- (ii) on a pixel by pixel basis writing the four band-radiances for each pixel in sequence.

The first of the above formats would be more suited to the drum write type of machine - which we hope eventually to acquire. The second format is more suited to small computer clustering applications, particularly in the "in-house-interactive" mode.

## 2.6.2 Supervised Clustering and Thematic Mapping

As part of the tape reformatting process, a simple coded picture output programme was developed. This represents each pixel's radiance level by one of a 47 character set on a non-overprinting line printer. It not only has aided in locating areas for the reformatting process, but has also formed the foundation for a "supervised" clustering package. This in turn has led to a simplistic but effective thematic mapping package. Neither of these are currently set up for interactive data manipulation, being geared more for the batch mode of operation. This is a temporary configuration as we pursue our programme development. Once the programmes are developed and documented, it will be a simple matter to hold the data files in Wellington and for accredited users throughout the country to use this national computer network to extract the answers most applicable to their investigations without intimately involving our section.

For both packages, the operator provides a radiance window for each band applicable to the target under consideration in the test area. The data is then scanned and those pixels passing through all four radiance windows are printed out symbolically. For those pixels passing through more than the first window, their default band number is optionally indicated.

In Figure 4 we present the result of such a supervised clustering approach applied to the Eyrewell Pine Forest around  $43.42^{\circ}\text{S}$ ,  $172.33^{\circ}\text{E}$ . This area was subjected to violent wind damage in early August. It was decided to run the supervised clustering package on the scenes covering this area taken on 2 August 1975 (2192-21265) and 31 October 1975 (2282-21254). For each scene the clustering revealed trees that exhibited "healthy" spectral signatures. Those blown down immediately prior to the 2 August scene have still appeared as "healthy" but by the 31 October scene the signatures have changed significantly. By colour compositing these two line printer outputs an assessment of the extent of the damage has been formed. Obviously by automatically counting pixel numbers in each output, a quantitative estimate of the area of damage may be deduced.



On compositing these two outputs, considerable difficulties were encountered in achieving correct feature superposition. Leaving aside the need for more detailed work on spectral signature determination and perturbations, together with the obviously unsatisfactory output device - enhanced by the need to mosaic a number of line printer outputs for one cluster output - it would seem that an analysis of the influences produced on CCT imagery by variations in satellite attitude and altitude is very necessary. This will be considered in the future as part of our CCT cartographic correction package.

We believed that in the absence of detailed information such as atmospheric extinction, backscattering contributions, soil types, variations in scan angles, etc., that a supervised mode was preferable in this first analysis, to the unsupervised mode. The training set approach has removed many uncertainties from this task.

Nonetheless, unsupervised clustering is being investigated, see section 2.7, both for comparison with the supervised approach and for the production of the most effective unsupervised package.

The thematic mapping package operates in a similar manner to the supervised clustering programmes - using the test area and classifying outwards from that. Currently we are using our Darfield test site as a target in testing this package and are classifying into three areas: Pine Forest, High Vigour crops, e.g. alfalfa, and Ploughed Land. These three areas have been set by the operational restrictions on the number of channels that can be reliably registered and printed at the one time using our I<sup>2</sup>s Colour Additive Viewer.

The result of such a thematic mapping package applied to part of our Darfield test area is presented in Figure 5. By default the path of the river may also be inferred. In Figure 5 the pine forest is shown as deep blue, the high vigour crop as green and ploughed land as red. The yellow and purple coding reveals areas that fall into more than one of these three classes. This underlines the need for more detailed investigatory work into the question of what constitutes a spectral signature. Again an automatic pixel

count for each target would quickly yield the acreage covered by that target in the thematically mapped scene.

A comparison of figures 4 and 5 with 6 reveals details of the forest blow down and the three thematically mapped targets using the two products - CCT and photographic.

In Figure 6, the forest areas show as dark green, the blow down regions as brown, the high vigour crops as hues of red and the ploughed land as blue - with the obvious exception of the river target.

## 2.7 Computer analysis of Test Areas

A library of computer programs has been developed for processing and displaying a selected 128 x 128 pixel portion of a LANDSAT image on our HP2100 computer. Many of these programs have been documented (McDonnell 1976 a,b).

These programs have been used to analyse several test areas of about 4.4 miles square which are of interest to the co-investigators and ourselves. The results of some of these investigations are discussed in sections 3.1 and 3.2. At present our best display device for computer processed images is an electrostatic lineprinter. Colour composite images of our test areas are being produced regularly using electrostatic lineprinter outputs.

Spectral signatures are being studied for different crops in our agricultural test area near Darfield. At present our best method of determining signatures is as follows. A correctly scaled computer printout of the test area is produced which shows the particular radiance level (ranging from 0-127) of each pixel. A transparency of the test area is prepared to the same scale from a map, which shows all the relevant details such as roads and field boundaries. Signatures for each field are then read off by registering the transparency over the computer radiance display.

During this reporting period, digital image enhancement techniques have been studied in some detail. Progress made in this area is discussed in section 3.1.

The development of a program to perform unsupervised cluster analysis is continuing. The approach being adopted is to obtain two-dimensional projections of four-dimensional spectral space like those in Figures 8 a and b. The cluster positions are then found by correlating the maxima found in the different projections and checking their consistency. The advantages of this technique are that it is very fast and that it can be used to process a whole LANDSAT scene on a small computer. Results so far are not as good as had been hoped for. It seems likely that this is due to the effect of the many pixels that lie on the boundary between areas of two distinct cluster types. It is now intended to adopt the initial approach of Jayroe et al (1975) and remove these ambiguous signatures before clustering is attempted.

## 2.8 Collaboration with CSIRO, Australia

Fortuitously, both the remote sensing group at the Minerals Research Laboratories, CSIRO, Sydney, and ourselves use an HP2100 computer under the disk operating system to do much of our digital image processing. Dr A.A. Green of CSIRO has agreed to exchange computer programs with us. We hope that this close co-operation will eventually be of considerable benefit to us both.

## 2.9 LANDSAT Cartographic Reflector

As our cartographic correction programs advance it will be necessary to utilise known ground control points to correct the CCT imagery.

The following are some commonly occurring "points" that could be used for such control. Current mapping of New Zealand coastlines is based on the high water mark. LANDSAT II coverage is not always coincident with this condition. River courses will vary from their mapped position over a period of time. Usual surveys are generally based on trigonometrical stations sited frequently atop high points. Whilst these trig. point locations are usually quite distinct when viewed obliquely, they are often less apparent using a downward vertical view.

For these reasons it will become necessary to establish a matrix of other cartographically known control points for optimum use of the CCT cartographic correction programs. This same matrix can be used with the corrected LANDSAT imagery to revise established maps and to construct new maps for previously unsurveyed and featureless areas, e.g. deserts or ice fields.

Following the work reported by Evans (1974), on marking LANDSAT imagery using reflected sunlight, we have constructed a test rig to develop the technique for our needs. This is a joint project between the Lands and Survey Department - one of the co-investigators - and ourselves.

As our knowledge of the satellite's orbit is confined to its orbital track and attitude as revealed by the some 4-5 scenes taken around our test site, a beam pattern at satellite altitude of approximately 80 km diameter was desired. Using a four foot diameter stainless steel reflector bowed

to give a divergent beam of core angle  $5.1^\circ$  we hope to produce around 10% full scale deflections in each LANDSAT II MSS channel. This should be evident on the CCT product.

The unit was installed on Burnt Hill, Canterbury ( $43.38^\circ\text{S}$ ,  $172.14^\circ\text{E}$ ) for the 10 April 1976 overpass. We planned to support the study with solar irradiance measurements. Unfortunately 10/10 cloud cover prevailed over the test site at overpass time.

We now intend to move the unit to our manned field station at  $45.04^\circ\text{S}$ ,  $169.69^\circ\text{E}$ , and alert the staff there in response to telexed advice from NASA to us, of any possible "turn on" over the site. The unit should be in place and operational for the 22 June 1976 overpass. It will remain on site until the test has been completed. A smaller more portable unit will be constructed and tested later in the year. A technical report is in preparation.

## 2.10 Data Storage, Retrieval and Dissemination

As detailed in our first quarterly report the storage retrieval and dissemination of the 70 mm and 9 x 9 products is established and operational.

An inventory of all LANDSAT I, II imagery held by our co-investigators is in the process of being completed.

Reports detailing the use of our computerised information retrieval system, its creation and modification, have been prepared and circulated.

To date we have received two LANDSAT II CCT sets with another four on order from EROS. Each new tape set is immediately copied to the central IBM 370/168 tape library files with a duplicate set being produced. The original is then archived within our laboratory for ultimate return to EROS. At this time only our section has the capability of using this CCT data directly. As the computerised interpretation develops other accredited users will be able to access our central computer, and its files, through a computer network. We hope that this "link-through" facility will be operational by late 1976.

## 2.11 PEACESAT

Through the co-operation of the Wellington Polytechnic this link through to the Goddard Space Flight Centre, with staff from PEL and other interested groups speaking to NASA staff, has continued to be most useful. Not only have the discussions helped us utilise the LANDSAT data more effectively, but through the PEACESAT link throughout the Pacific, brought the concept of LANDSAT to interested parties from Samoa through Sarawak. Indeed, on 10 June Fiji arranged a link to Wellington to discuss the LANDSAT and general remote sensing programs. These exchanges have been of tremendous advantage to all aspects of our CCT and general data interpretation and we are very grateful to the PEACESAT control authorities for making the time available to us and in particular to Dr R.D. Price and his colleagues at NASA for their very informative and encouraging interchanges.

## 3. ACCOMPLISHMENTS AND IMMEDIATE OBJECTIVES

### 3.1 Investigation of Image Enhancement Techniques

Many useful results have been found by human interpretation of colour composited LANDSAT images. However, much of the information available in a LANDSAT scene is lost when the scene is displayed photographically. This is because film non-linearities tend to lose both high and low density information and also because the eye cannot distinguish all the grey levels and colour tones that the photograph may be capable of producing. It is therefore of interest to study ways of enhancing an image so as to increase the amount of information a human observer may derive from it.

Let us assume that we have available a device which displays an image in 128 grey levels (0-127) which the eye sees as equal intensity increments. A typical single band of a LANDSAT image may have an intensity range of 20-50 on the CCT's. The traditional approach to enhancing such an image (Andrews 1976) is firstly to scale the intensity levels so that the range is 0-127. Secondly, histogram equalisation is carried out on the scaled intensity levels. This has the effect of making the occurrence of each grey level in the final image equally likely and thus maximises the amount of information which may be derived from the monochrome image.

The above approach works very well for monochrome images. The same technique has been used to individually enhance single bands of a LANDSAT image, three of which are then colour composited. Some impressive results have been produced using this method (Bernstein 1976). Figures 7 and 11 have been produced in this way but are limited by the quality of our display device. Figure 7 is a colour composite of the central Christchurch City area made from MSS bands 4, 5 and 7 which are printed as yellow magenta and cyan respectively. Hagley Park shows up clearly as red in the bottom centre of the picture as does the blue central city area to the right. The river Avon can be seen in black running from the right centre of Hagley Park to the centre of the right hand edge of the image. Farmland to the north of the city shows up red as do small parks scattered throughout the city. Suburban housing areas range from purple to orange as the amount of vegetation increases. Suburban shopping centres, and major roads and railway lines are also visible.

The range of colours displayed in each of Figures 7 and 11 is considerably less than the maximum possible range obtainable from the display device. Thus the above enhancement technique is inefficient when used for colour imagery. This inefficiency is due to the fact that the spectral bands are strongly correlated. This causes the predominance of shades of brown in Figure 3. We find that for all the test areas we have studied bands 4 and 5 and the reversals of bands 6 and 7, are approximately proportional to each other. This correlation is illustrated by the spectral distribution plots in Figures 8 a and b in which the number of pixels for which a particular two-band signature occurs is plotted as a density. Figure 8c is the plot corresponding to Figure 8b after the above histogram equalisation enhancement technique has been carried out. In this figure a diagonal band of signatures are the most likely to occur. However, ideally all possible signatures should be equally likely.

To overcome the above problem it is necessary to colour composite images which have the least possible correlation. New uncorrelated images may be produced as required by taking linear combinations of the original four image bands.

For a two-band image the best way of doing this is to rotate and translate the axes of the spectral distribution plot corresponding to Figure 8b such that the principal axis of the spectral distribution is one of the new axes, and the centre of mass of the spectral distribution is the new origin. The two new spectral bands resulting from this transformation are then scaled so that they range from 0-127 and finally enhanced using the technique of histogram equalisation. The spectral distribution plot obtained using this technique corresponding to that in Figure 8b is shown in Figure 8d. It is clear that a much wider range of two-band signatures occurs in Figure 8c than in Figure 8d. Care should be taken to minimise the quantisation errors involved in the above operations.

The effect of the above axis transformation in spectral distribution space is to produce two new images which would have been produced by using spectral filters which are linear combinations of the filters used to produce the original images. Note that negative transmissivity allowable for the new artificial filters. This is illustrated in Figure 9.

The colour enhancement procedure for three image bands is analogous to the above procedure for two image bands. A three-dimensional (3-D) axis transformation is simply required instead of a two-dimensional (2-D) one. The first new axis is the principal axis as above. The second new axis, or secondary axis, is the principal axis of the 2-D spectral distribution formed by taking a projection of the original 3-D spectral distribution parallel to the first new axis.

The above 2-D and 3-D colour enhancement procedures can be carried out in a reasonable time on a small computer. Four passes of the image data to be enhanced are required. The first pass of the image data is used to find the principal axis, the second to find the secondary axis, and the third to obtain the data required for histogram equalisation. The enhanced image is produced in the fourth pass of the data. The requirement of four passes of the image data does not compare too unfavourably with the two passes required for enhancement by histogram equalisation. In our next quarterly



result has emerged, and that is the identification of forest blow-down areas described in sections 2.6.2 and 3.2. The investigation will now attempt to assess the condition of these areas from LANDSAT images taken at different times. At the conclusion of this investigation, it should be possible to assess the results in terms of cost benefit, which could be of considerable importance.

## 5. PUBLICATIONS

### 5.1 PEL Reports

M.J. McDonnell "Use of the Varian Statos 31 Printer to display Landsat images", PEL Report No. 507, March 1976.

I.L. Thomas and P.J. Ellis "User guide to the Rapid Imagery Location Indexing System (RILIS)", PEL Report No. 516, April 1976.

I.L. Thomas "Control TSB Programmes for the RILIS Programme Package", PEL Report No. 517, April 1976.

M.J. McDonnell "A library of computer programs for processing Landsat imagery on an HP2100 computer", PEL Report No. 519, April 1976.

P.J. Ellis "Visit to Remote Sensing Section CSIRO Australia", PEL Overseas Report No. 70, May 1976.

### 5.2 Newsletter

Since our last quarterly report, we have instigated an informal "Remote Sensing Newsletter". This is of a similar style to the NASA LANDSAT Newsletter, and contains jottings on developments of interest to those working on remote sensing topics in New Zealand. It is planned to produce these newsletters at irregular intervals, perhaps aiming at a quarterly periodicity, and often add the latest "NASA LANDSAT Newsletter" for further interest. Our current circulation of some sixty copies extends throughout New Zealand and includes groups in the surrounding Pacific Islands and Australia.

## 6.7. PROBLEMS, DATA QUALITY AND DELIVERY

### 6.1 CCT

From the time we receive a photographic product for a scene, appraise it and place an order for that scene's CCT's to its receipt, often some 3-4 months elapse. We realise that often the master tapes need to be prepared, etc., but wonder if this lag of 3-4 months can in any way be shortened. Currently then, some 6-7 months pass, between the actual recording of the scene over the country, and CCT receipt. A briefer interval would bring LANDSAT data more firmly into current studies.

Each of the four CCT's contains a vertical strip of a full LANDSAT scene. Thus only a quarter of each scan line is on each CCT. This is an inconvenient format from our point of view because we wish to write full scenes onto film using a photowrite machine. For ultimately doing this it is desirable that the CCT's be reformatted so that each block contains a full scan line with interleaved data for the four spectral bands. We can do this but it is time consuming and expensive. It would be preferable if the tapes we receive from NASA were formatted in this way in the first place.

### 6.2 Computer Print-out Co-ordinates

There have been some instances where the corner point geographic co-ordinates furnished in the computerised scene "Standing Request Processing Report" differ from those actually recorded in the photographic product for that scene. This has been noticed initially in some 2-3 scenes with a discrepancy magnitude of up to 10 minutes in latitude and/or longitude. Before we can reliably place these corner points into our computerised data files, we need to investigate this problem more fully.

### 6.3 LANDSAT II Data Users Handbook

We continue to use our LANDSAT I handbook as a reference for this LANDSAT II programme, as to date we have not received the above Handbook. Particularly for projects such as the cartographic reflector, in the areas of orbit altitude control and sensor responses, etc., the relevant handbook would be of great value. It would also be of great value,

when coupled with the CCT manuals, for CCT processing, especially in the area of sensor calibration.

#### 6.4 Data Products Received

In Figure 1 of the report written by our Lands & Survey Co-investigator we indicate the scenes received under this programme to 1 June 1976. Usually we receive the computerised "Standing Request Processing Report" some 1-2 months after the scene has been recorded and the photographic product about a month later.

We are extremely grateful for the effort NASA have made in supporting our aerial underflight programmes over Darfield. On three occasions this has been possible. Unfortunately the last (February 1976) was notable for its cloud cover. This effort has been of tremendous assistance in furthering all aspects of our remote sensing programme.

## 8 & 9. RECOMMENDATIONS AND CONCLUSIONS

The following main topics have been covered in this report:

- (a) An investigation of the causes of misregistration in our colour compositing of 70 mm transparencies.
- (b) A method of improving the alignment of the colour additive viewer, and of our multispectral camera system.
- (c) Classification of major targets using a supervised clustering approach.
- (d) Development of a system for pre-processing CCT data to enhance differences between bands in the colour composite.
- (e) The use of CCT data to identify forest blow-down areas in Eyrewell State Forest.
- (f) Production of positive and negative transparency colour composites to aid interpretation of geological features.
- (g) Development of cartographic reflectors.

Much of this work arises directly from the requests and comments of the Co-investigators and other potential users such as the N.Z. Forest Service. If subsequent work shows that the condition of blown down forest areas can be successfully estimated from LANDSAT data, this application will have considerable financial significance. We note that the Dept of Lands and Survey is making increasing use of this imagery in cartographic applications such as hill shading and map correction, and possibly this could represent the first "operational" use of LANDSAT data in this country.

In the last context we feel that spatial rectification of LANDSAT images will be necessary in the near future, and intend to take steps to implement this, either by making use of existing programmes, or by developing our own.

It is interesting to note that certain applications such as the forest work have already benefited from the increased dynamic resolution available from CCT's. In many cases, however, including this one, it is best to pre-process the digital imagery, and rely on "eyeball" methods for the final interpretation. Other applications will continue to use the photographic products in the foreseeable future.

## ACKNOWLEDGEMENTS

We would like to thank the staff of the EROS Data Centre for all their efforts on our behalf, particularly for the steady flow of information and image products, and for the prompt responses to our questions and requests for geographic searches.

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1, 40-57.
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reflector. Photogrammetric Engineering 40, 6, 665-671.
- (See also Section 5).

TABLE ONE

26 a

Measured co-ordinates and distances from nominal positions (Xn, Yn), of fiducial marks, using the co-ordinate system shown in Fig. 2. All dimensions are in mm.

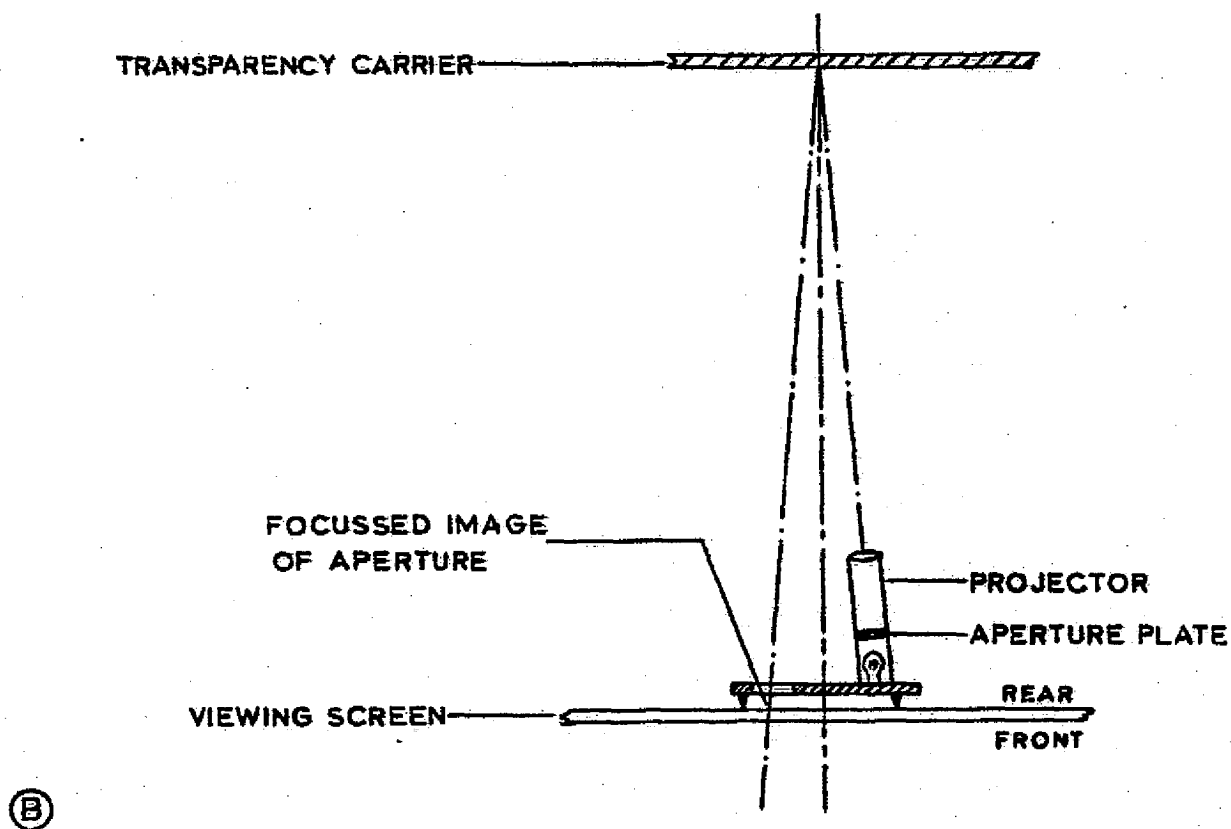
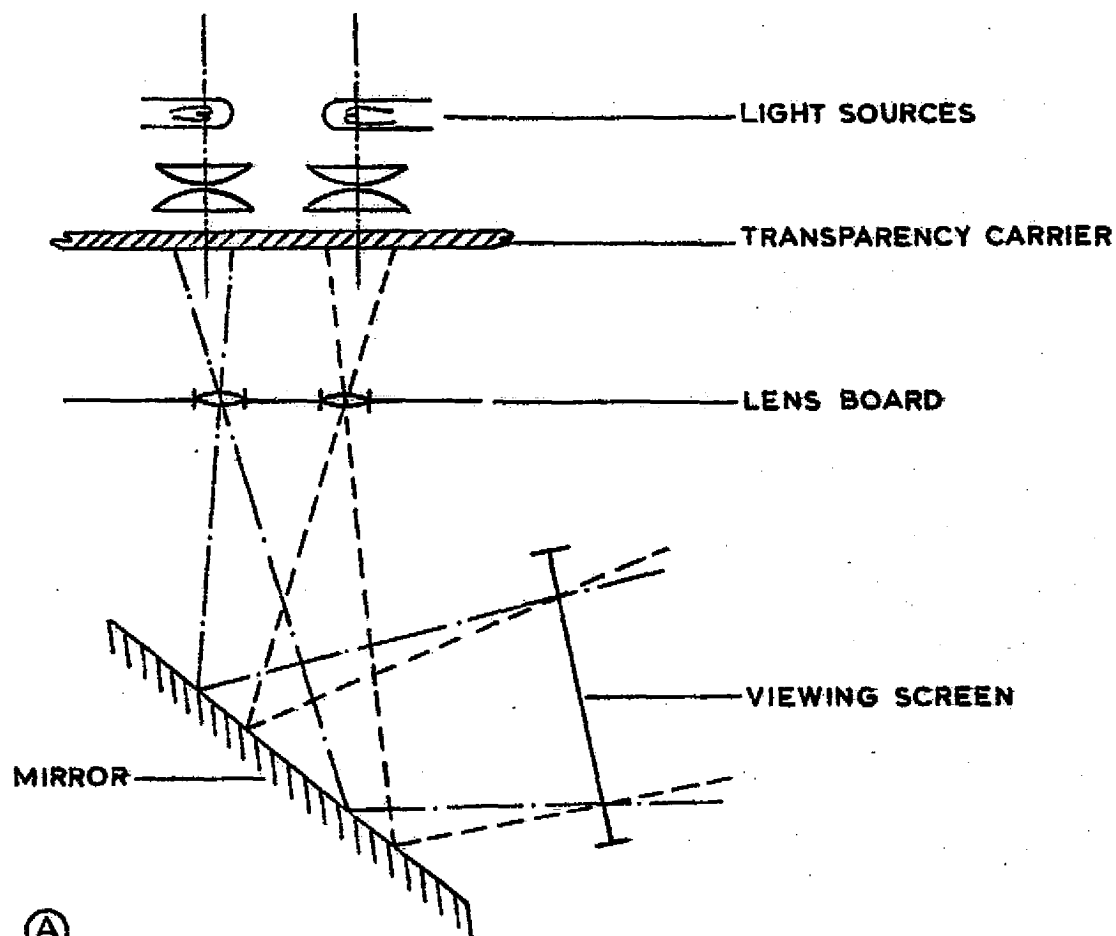
SCENE	FIDUCIAL MARK	CO-ORDINATE	MSS BAND NUMBER			
			4	5	6	7
2334-21123 (22 DEC 1975)	F2	X	-0.010	0.007	-0.002	-0.008
		Y	60.374	60.377	60.368	60.367
		X-Xn	-0.010	0.007	-0.002	-0.008
		Y-Yn	0.874	0.877	0.868	0.867
	F3	X	58.588	58.601	58.594	58.582
		Y	60.374	60.362	60.375	60.366
		X-Xn	-0.012	0.001	-0.006	-0.018
		Y-Yn	0.874	0.862	0.875	0.866
	F4	X	58.598	58.590	58.592	58.593
		Y	0.000	0.000	0.000	0.000
		X-Xn	-0.002	-0.010	-0.008	-0.007
		Y-Yn	0.000	0.000	0.000	0.000
2389-21172 (15 FEB 1976)	F2	X	-0.044	-0.029	-0.018	-0.004
		Y	60.004	59.980	59.979	59.989
		X-Xn	-0.044	-0.029	-0.018	-0.004
		Y-Yn	0.504	0.480	0.479	0.489
	F3	X	58.537	58.545	58.554	58.565
		Y	60.027	60.012	60.002	59.993
		X-Xn	-0.063	-0.055	-0.046	-0.035
		Y-Yn	0.527	0.512	0.502	0.493
	F4	X	58.576	58.569	58.567	58.567
		Y	0.000	0.000	0.000	0.000
		X-Xn	-0.024	-0.031	-0.033	-0.033
		Y-Yn	0.000	0.000	0.000	0.000

TABLE ONE (Cont'd)

26 B

SCENE	FIDUCIAL MARK	CO-ORDINATE	MSS BAND BUMBER			
			4	5	6	7
2282-21254 (31 OCT 1975)	F2	X	-0.060	-0.043	-0.059	-0.056
		Y	59.973	59.977	59.972	59.959
		X-Xn	-0.060	-0.043	-0.059	-0.056
		Y-Yn	0.473	0.477	0.472	0.459
	F3	X	58.535	58.546	58.541	58.545
		Y	59.973	59.960	59.951	59.972
		X-Xn	-0.065	-0.054	-0.059	-0.055
		Y-Yn	0.473	0.460	0.451	0.472
	F4	X	58.596	58.594	58.590	58.601
		Y	0.000	0.000	0.000	0.000
		X-Xn	-0.004	-0.006	-0.010	0.001
		Y-Yn	0.000	0.000	0.000	0.000
2192-21265 (2 AUG 1975)	F2	X	0.010	0.000	-0.004	-0.009
		Y	60.355	60.340	60.333	60.348
		X-Xn	0.010	0.000	-0.004	-0.009
		Y-Yn	0.855	0.840	0.833	0.848
	F3	X	58.587	58.576	58.575	58.571
		Y	60.352	60.374	60.369	60.363
		X-Xn	-0.013	-0.014	-0.025	-0.029
		Y-Yn	0.852	0.874	0.869	0.863
	F4	X	58.581	58.581	58.585	58.588
		Y	0.000	0.000	0.000	0.000
		X-Xn	-0.019	-0.019	-0.015	-0.012
		Y-Yn	0.000	0.000	0.000	0.000

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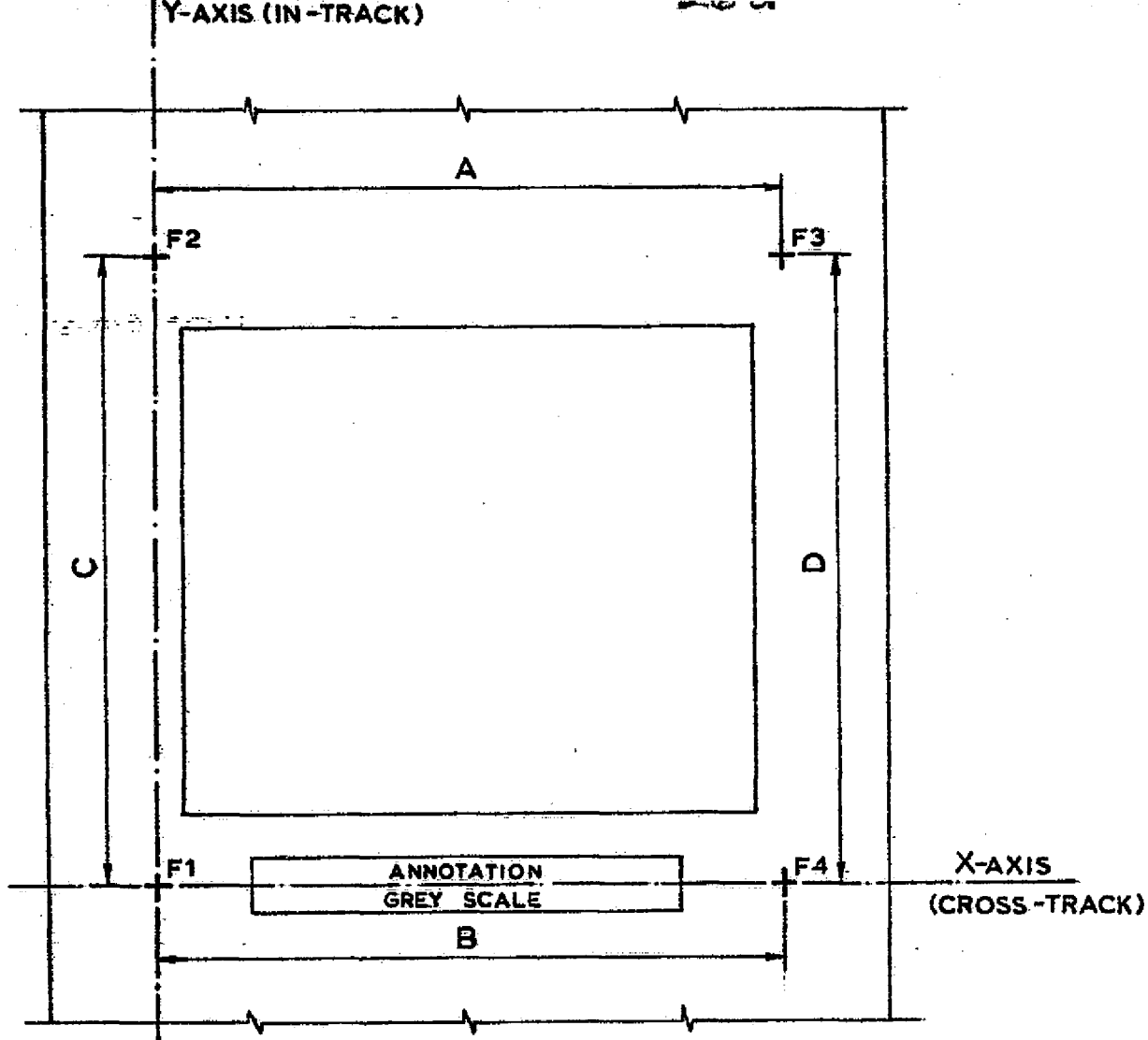


(A) COLOUR ADDITIVE VIEWER SCHEMATIC

(B) ALIGNMENT SYSTEM SCHEMATIC

FIG. No 1





NOMINAL FIDUCIAL MARK SEPARATION :-

A	}	58.6 mm	}	OBTAINED FROM ERTS-1 DATA USERS HANDBOOK
B				
C	}	59.5 mm		
D				

X-AXIS PASSES THROUGH F1 AND F4

F1 = CO-ORDINATE ORIGIN

CO-ORDINATE SYSTEM USED TO DESCRIBE  
POSITIONS OF FIDUCIAL MARKS



E176-001 S039-301 E176-301 E177-001  
 22DEC75 C S38-43/E176-46 N S38-45/E176-51 MSS 45 7 R SUN EL49 AZ001 191-4659-A-I-N-D-ZL NASA ERTS E-2334-21123-7 01

Figure 3 - Central North Island colour composite produced from standard 70 mm negative using re-aligned colour additive viewer.

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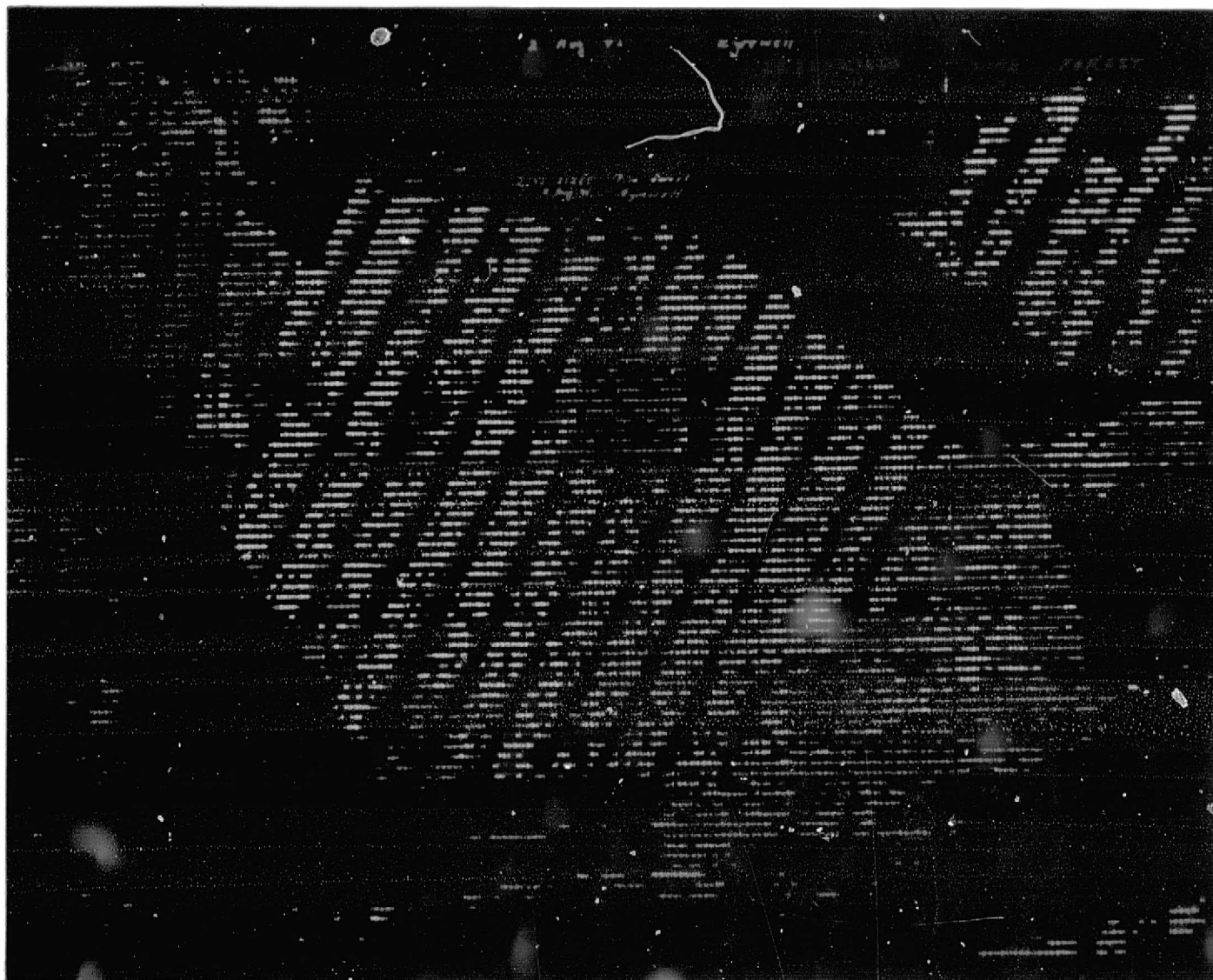


Figure 4 - A colour coded comparison of the extent of damage to the Eyrewell Forest. Supervised clustering applied to "healthy" trees for the 2 August 1975 (2192-21265) scene shows red and for the 31 October 1975 (2282-21254) scene shows either yellow or green. The difference between the two areas is indicative of the extent of the damaged area.

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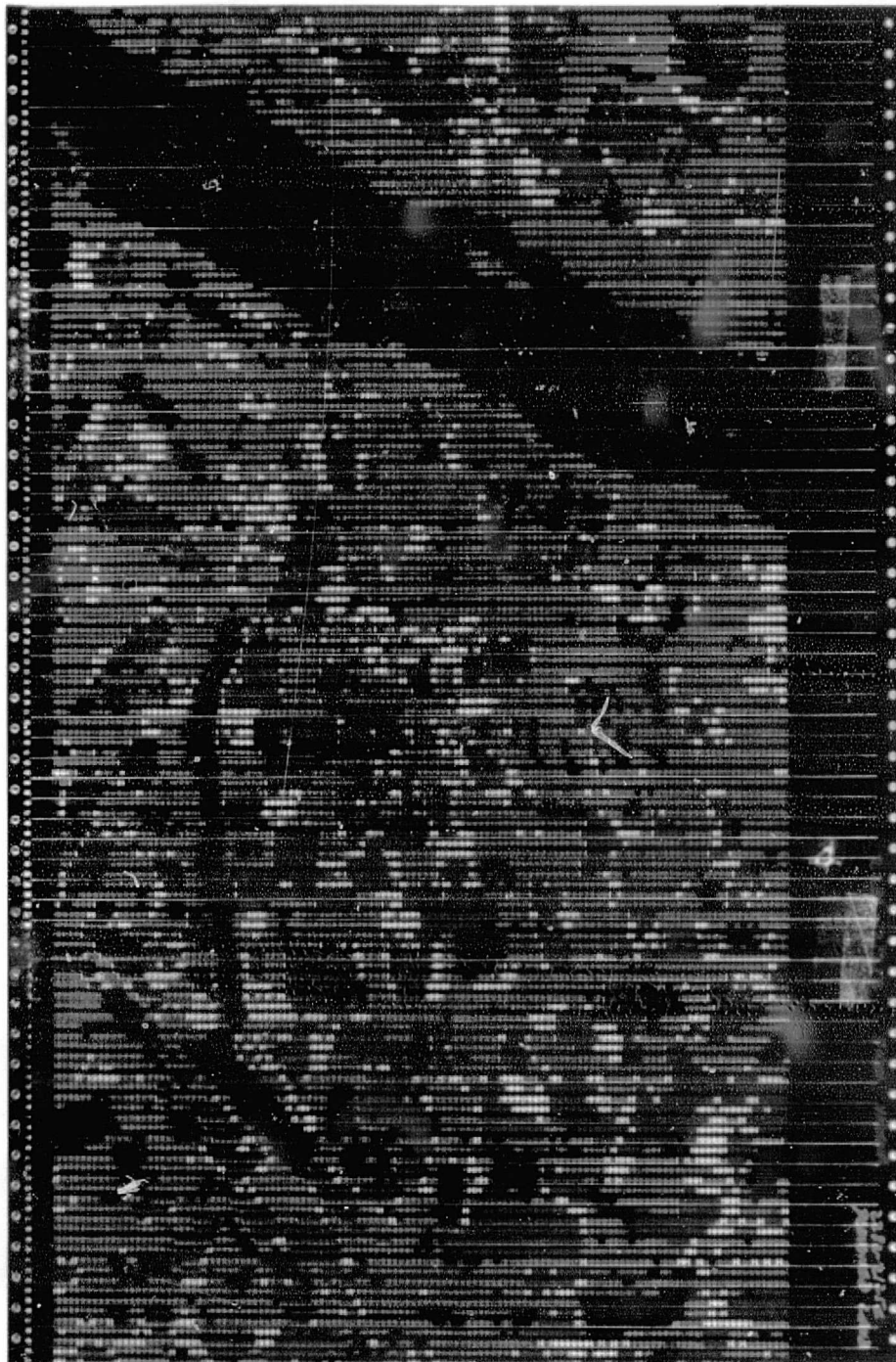


Figure 5 - A thematic map of part of the Darfield test area  
for the 31 October 1975 (2282-21254) scene

Red	-	ploughed land
Green	-	high vigour crop
Dark Blue	-	pine forest

Yellow and Purple areas signify regions where  
spectral signature classifications overlap -  
see text.





Figure 6 - A colour composited enlargement of the 70 mm photo product for 31 October 1975 (2282-21254) scene. Eyrewell Forest is visible above the river, and the distinctive pine forest shelter belt, on the west of the area considered in Figure 5, can be seen to the left edge of this figure.



Figure 7 - Computer generated colour composite of Central Christchurch City area from LANDSAT II, 31 October 1975. (Bands 4, 5 and 7 are printed as yellow, magenta and cyan respectively.)

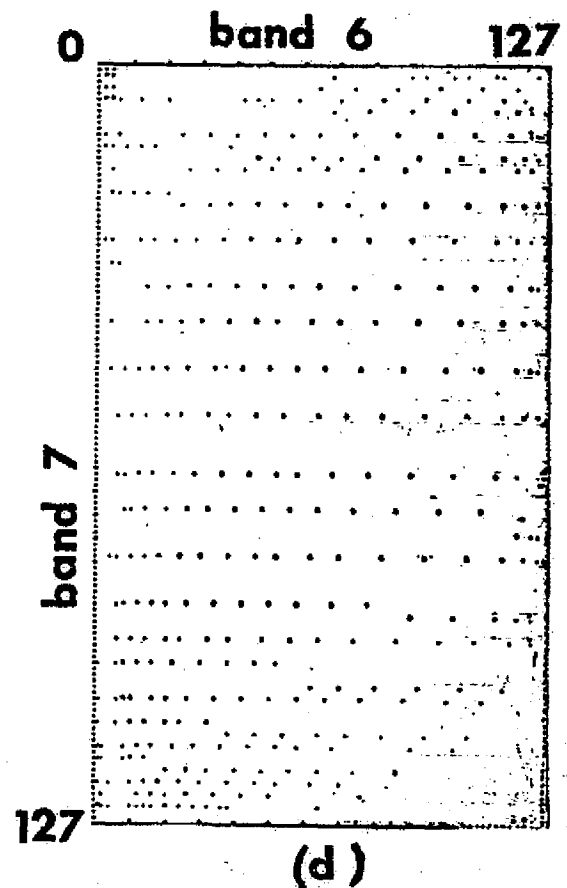
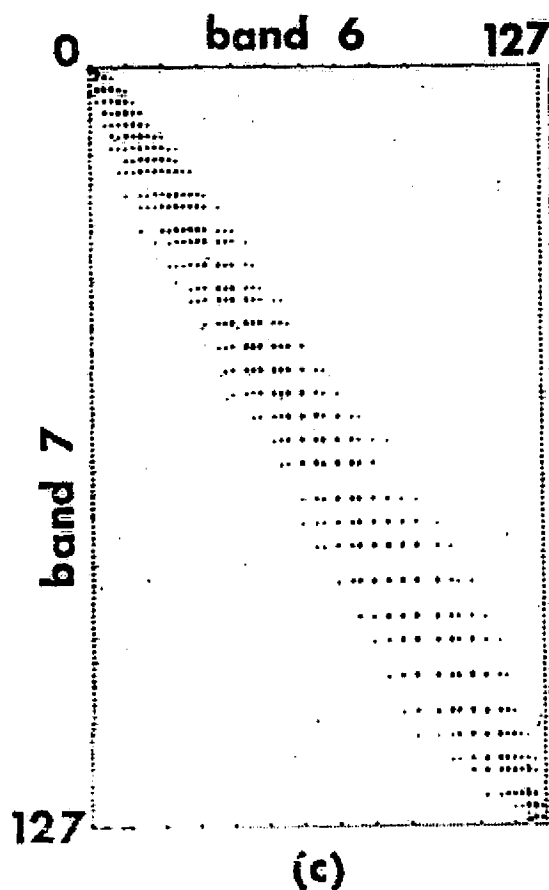
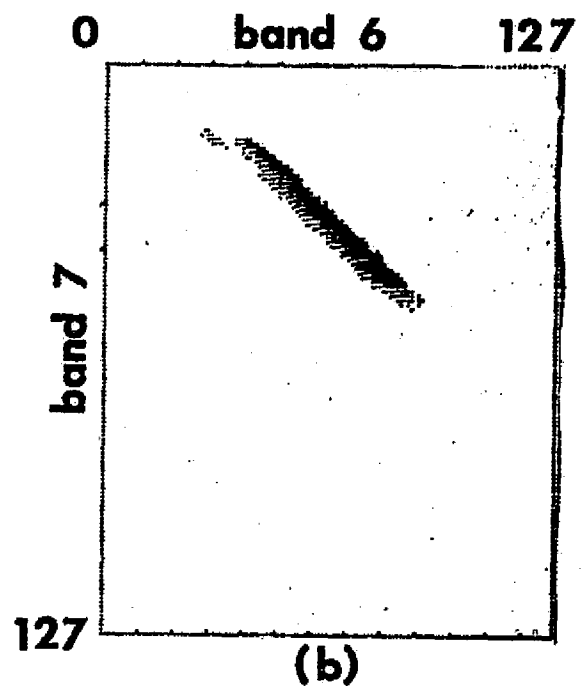
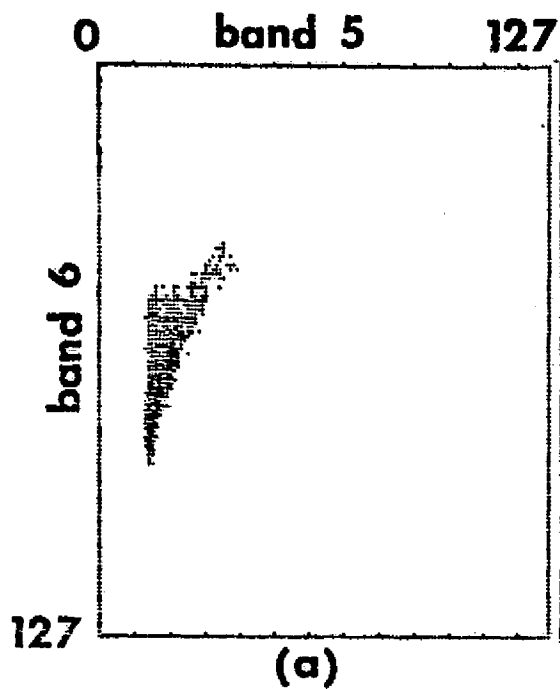
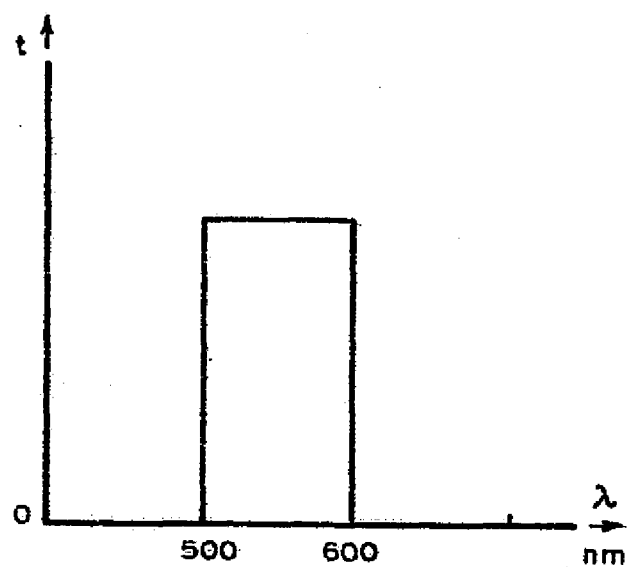
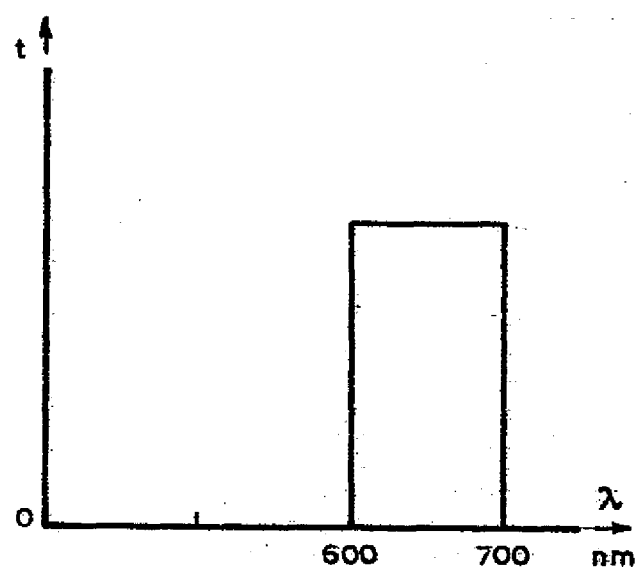


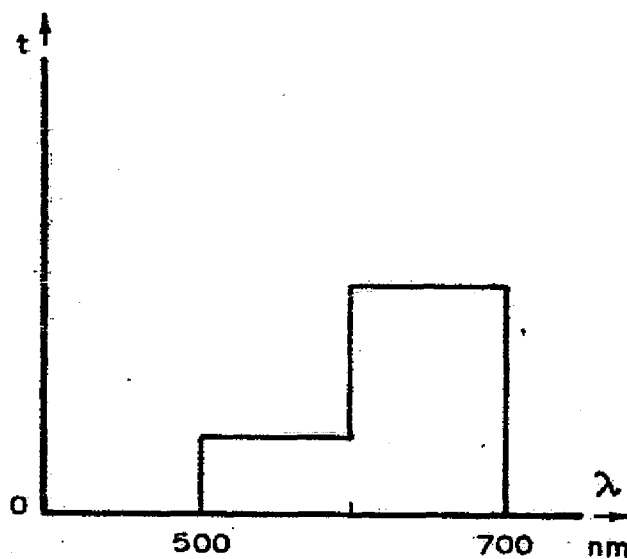
Figure 8 - Spectral distribution plots for two bands of a Landsat image. (a) bands 5 vs 6 and (b) bands 6 vs 7 for Darfield test area (31 October 1975); (c) result of scaling image corresponding to (b) and enhancing it using histogram equalisation; (d) result of colour enhancing image corresponding to (b).



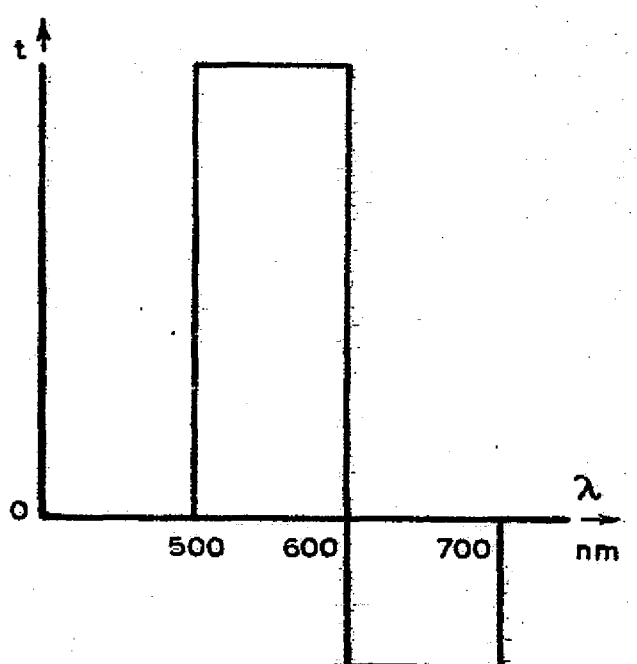
(a)



(b)



(c)



(d)

Nominal filter transmissivity  $t$  for Landsat bands (a) 4 and (b) 5; (c) and (d) equivalent filter responses after a two-band colour enhancement.



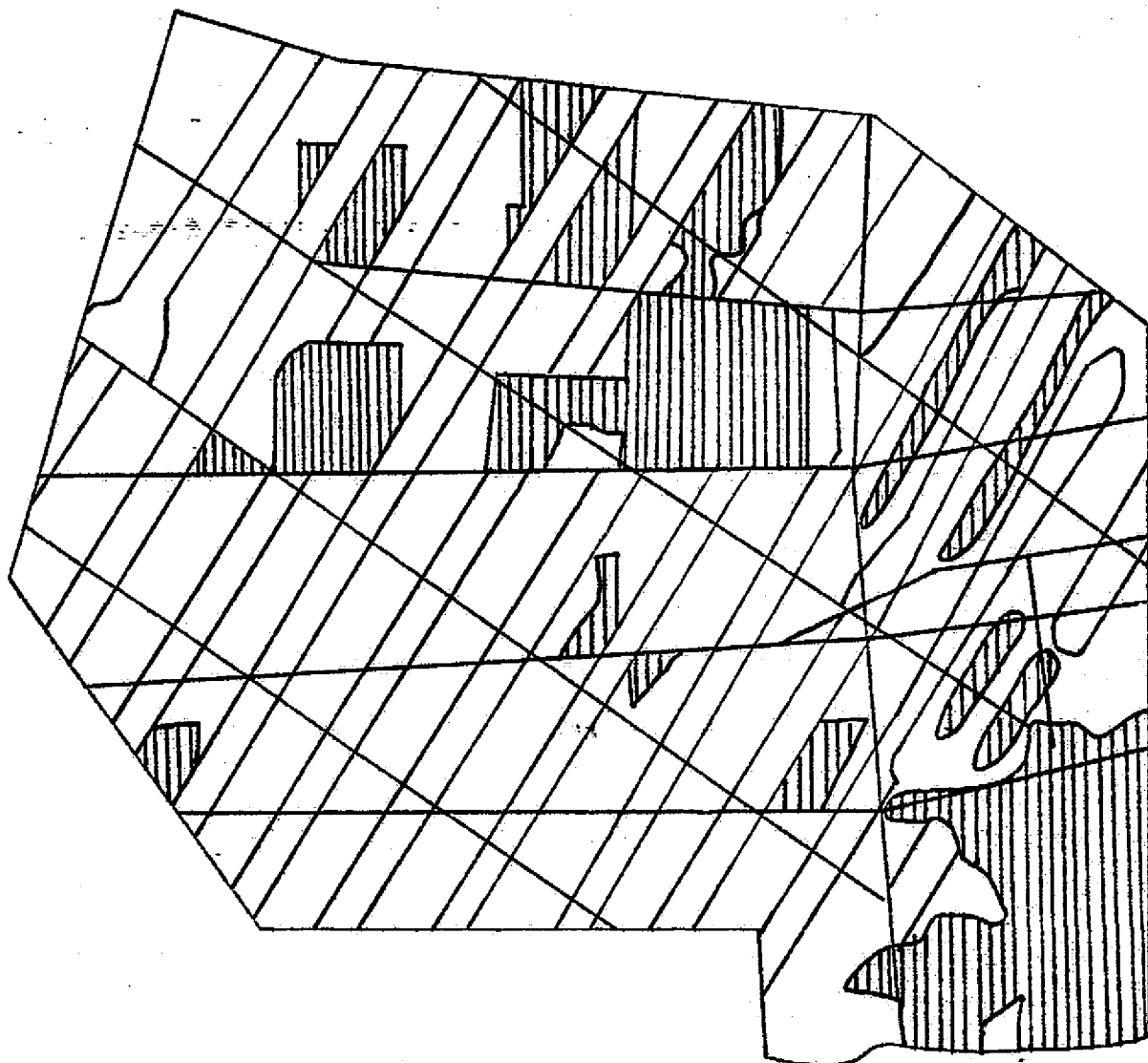


Figure 10 - Ground truth map of Eyrewell State Forest  
(corresponding to Figure 11) showing as shaded  
the areas of forest blow-down.

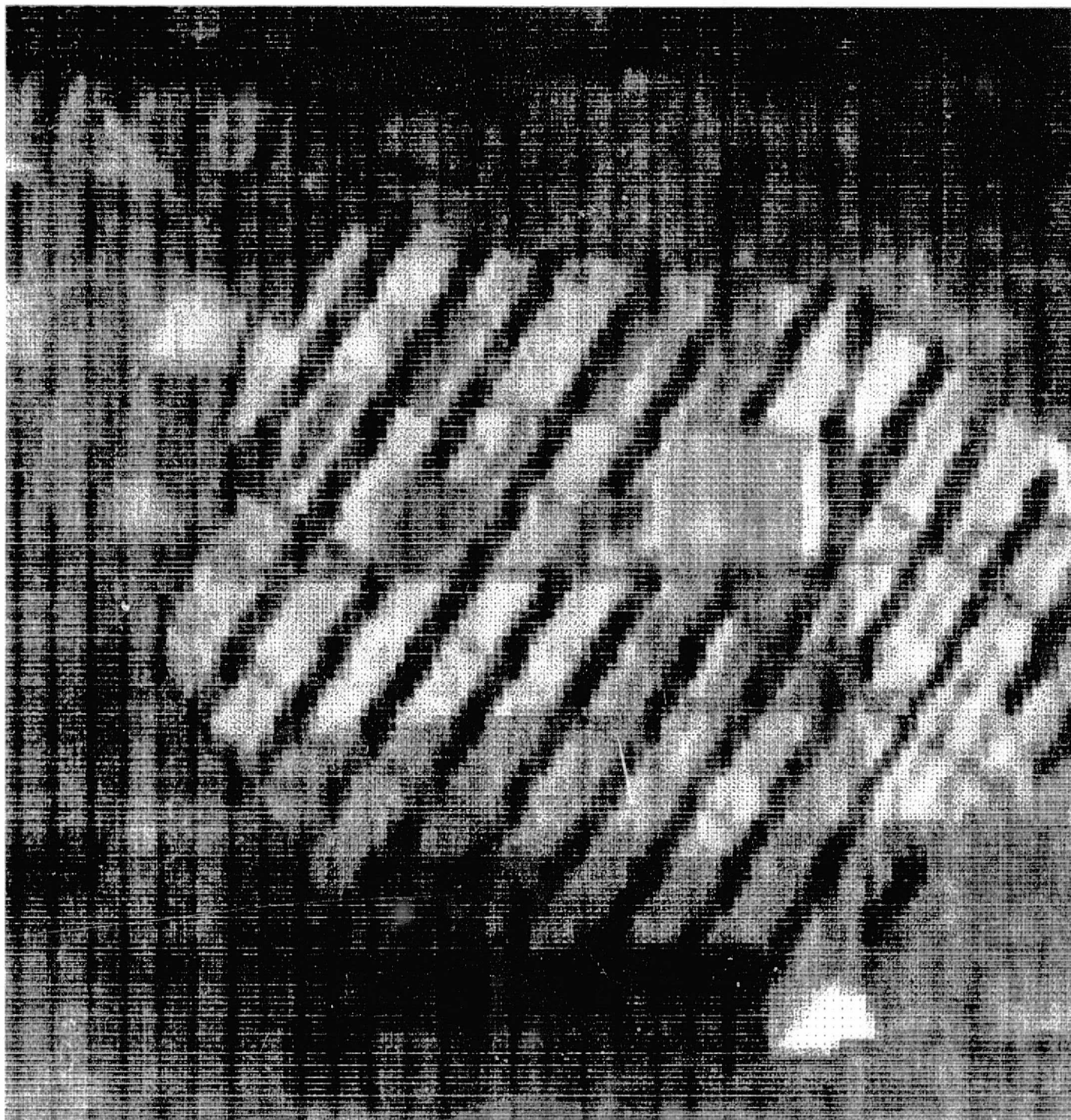


Figure 11 - Computer generated colour composite of Eyrewell  
State Forest from LANDSAT II, 31 October 1975.  
(Bands 4, 5 and 7 are printed as yellow, magenta,  
and cyan respectively.)

26 N  
PART II

MAPPING LAND USE AND ENVIRONMENTAL  
STUDIES IN NEW ZEALAND

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## INTRODUCTION

Although at the beginning of the programme we were slow starters, our progress has been gathering momentum in a satisfactory manner. The people involved in the Lands and Survey developments are all technicians. Without exception, the aims of these people are to discover what can be gained cartographically from the data received from EROS and use it as quickly as possible.

A most significant factor in the Lands and Survey interest in applying LANDSAT 2 imagery to cartography, is that a new mapping series is about to be implemented.

For many areas this will be the first major mapping revision and the application of satellite imagery to revision is extremely important in this country's cartographic development. This applies especially in regard to the 1:250,000 topographic series and in a reappraisal of Land Use mapping.

1.0 The problems in applying LANDSAT imagery to the cartographic technique of hill shading were of a minor nature and centred around the provision of the best method of presenting the information to the hill shading artist.

1.1 As stated in our last report, Aeronautical Charting personnel are already using the imagery for hill shading at scales of 1:500,000 and under. This is being carried out by interpreting 1:1,000,000 colour composites and monochrome prints and relating the information to the map.

1.2 In progressing to the NZMS 18 series of 1:250,000 scale maps, it became apparent that 1:1,000,000 scale imagery was not an ideal scale from which to operate.

1.3 Different methods of presentation were tried and two proved of considerable merit. First was to provide the artist with a table top microfilm viewer and the appropriate band 6 70 mm positive of the area concerned.

1.4 For the purpose of the test a Vantage 11 microform reader equipped with Lens B enlarging to x17 and Lens D enlarging to x25 was used. The projected image quality was excellent.

1.5 This method proved to be a useful tool for hill shading interpretation specifically and interpretation generally. However, since this method exposes the transparency to an inordinate amount of heat and unfiltered light, it was put aside in favour of the second procedure described as follows.

1.6 Using a Chromega Enlarger accurately scaled enlargements at 1:250,000 scale were produced using band 6 70 mm negatives. To minimise differential expansion/contraction effects, print size was restricted to 8" x 10".. This size also facilitated easier handling and examination by the artist, at the same time it was possible to position a map outline trace directly over the print with accuracy.

1.7 A production 1:250,000 sheet is being prepared of the Nelson area in the South Island. LANDSAT 2 will provide all the information required for hill shading (except for areas obscured by cloud).

1.8 Preparations are under way to afford the same facility in aiding the artist on other 1:250,000 scale sheets due for revision.

1.9 As will be discussed in the report on the Photogram-metric Branch progress image accuracy was proved to the required tolerance for 1:250,000 revision purposes.

1.10 At present the method under trial for the purpose of transferring information from the image to the map is as follows:

Accurately scaled 8" x 10" photographic enlargements have been produced of the test area. The procedure involves the map overlay in direct contact with the photographic print.

1.11 The same reasons that were expressed in favour of 8" x 10" format for hill shading apply here, i.e. minimal expansion/contraction and ease of handling. It also has the advantage of allowing the reviser to work at his own draughting table.

1.12 Although we are not yet able to give detailed findings in this report, nevertheless the revisers involved are enthusiastic over progress thus far.

2.0 Aeronautical Charting Division in their limited use of the imagery are still satisfied with progress thus far and their main comment has been for greater coverage.

3.0 The Planning and Inventory Division (incorrectly named Evaluation and Planning Branch in the last report) have not been able to progress too far in applying the imagery to their needs.

3.1 Two main factors have been responsible for this hold up. First is an acute staff shortage within their ranks; and second is the failure to make our I<sup>2</sup>S camera function properly to give the desired results in underflying.

3.2 The camera is presently at the DSIR workshops for correction and by August it is hoped that Planning and Inventory Division will have begun their programme.

3.3 This situation has been disappointing because it is felt that this Division has possibly the most to gain from both LANDSAT and I<sup>2</sup>S imagery. However, by the time that the next report is due, work will have begun on the project.

4.0 Within Photogrammetric Branch trials have been made using a Zeiss Planicart E3 photogrammetric plotting instrument with 1:1,000,000 monochrome transparencies employed in a mono viewing mode.

4.1 Plotting has been carried out in tests at three scales 1:250,000, 1:63360 and 1:25,000

Results have been encouraging but several disquieting facts have come to light during the tests. These facts are as follows.

4.2 The transparency material received from Eros Data Centre at both format sizes of 70 mm and 9" x 9" have not been consistent in measurements taken between registration marks at the corners of the image margins.

4.3 Further, distances between recognisable ground points on the four band images of almost all scenes at a scale of 1:1,000,000 can differ in measurement by as much as 0.25 mm.

4.4 It may seem hypercritical to point out these dimensional variations at 1:1000000 scale but when enlarged plots are produced at enlargement factors in excess of  $x^4$ , then these variations become a problem.

4.5 Provision of colour photowrite facilities would be the ideal answer to this problem.

Added to the a/m problems are the not inconsiderable differences that arise in the recognition and marking of ground control points on the imagery.

4.6 Several methods have been tried in pursuance of accurate marking. These range from pricker microscopes to the Wild P.U.G.4 point transfer instrument. None have proved suitable in themselves and errors of up to 1.5 mm in marking are not unknown so far.

4.7 Generally, second or third attempts at point marking produce accurate results and where the interpreter has personal knowledge of the control point ground position, then the required answer is obtained much more quickly.

4.8 A long term solution to this problem undoubtedly lies with our reflector programme. DSIR and Lands and Survey are both working to this end.

4.9 A detailed report on results and progress with our plotting tests at scales 1:250,000 and 1:63360 will be presented in the next report. What follows presents the whys and wherefores of our tests at scale 1:25,000.

4.10 Once more employing the Planicart E3 plotting instrument linked through Selsyn drive motors to the Carl Zeiss EZ4 plotting table, a test designed to provide an assessment of image accuracy was carried out at a scale of 1:25,000.

REPRODUCIBILITY OF THE  
ORIGINAL PAGE IS POOR



4.11 An area of the Marlborough Sounds had recently been mapped at a scale of 1:25,000. This was accomplished using conventional photogrammetric practice.

4.12 Using a 1:1,000,000 scale band 6 LANDSAT 2 transparency a photogrammetric plot was made of the same area. This involved an enlargement factor of x40 from source material to plotted product, in this the Planicart proved invaluable.

4.13 Direct comparison of the two plots revealed a mean variation in detail positioning of  $\pm 2$  mm over a plotting area of 1 metre<sup>2</sup>.

4.14. It follows from this result that at a scale of 1:250,000 scale image accuracy could be as good as  $\pm 0.2$  mm and would therefore be sufficiently accurate for productive revision work at 1:250,000 scale.

4.15 The LANDSAT 2 image index sheet as it appeared in the last report was adequate for its purpose at the time. With the arrival of seventeen more scenes it was felt that improvements could and should be made.

4.16 Orbital tracks were replotted giving a converging rather than parallel configuration to the overall picture. Co-ordinates of known and predicted scene centres were plotted and a more logical image index map numbering system applied.

4.17 The column heading "Comments" was deleted and replaced with "Sequential ID No" to make the sheet compatible with system used by the Remote Sensing Section at DSIR.

4.18 The New Mk II index sheet is shown in figure 1. The index sheet for LANDSAT 1 is unchanged as yet.

5.0 Figures 2, 3 and 4 display some aspects of our endeavours in the tests with reflectors. Since the majority of the mathematics involved in this problem have been handled in truly expert fashion by Dr Ian Thomas of DSIR Remote Sensing Section, then he will be presenting his own detailed report on the subject.

5.1 Lands and Survey will simply present at this point a description of the build up to the attempt on the 11 April overpass.

5.2 The reflector as shown in figure 2 is constructed using a particle board backing for the reflector. The board is hinged to a box packed with foam rubber so that for storage purposes the reflector back becomes the lid of the box and the reflector itself rests on the foam rubber in the box.

5.3 Using a four foot diameter disc of 20 gauge mirror finish stainless steel, the computed curve required to give the necessary reflected beam angle width was acquired by building up a contour model. Card of a suitable thickness was used. Horizontal and Vertical intervals for these contours were computed by Ian Thomas.

5.4 After completion of the contour model, the stainless steel was laid on top and allowed to take up the curve needed. The disc was then secured to the backing board by wood screws spaced at approx. 5" intervals around the circumference.

5.5 In the bottom right hand corner a glass mirror was placed as part of the alignment device produced by DSIR's Remote Sensing team. The mechanics of this device will be described by them in their submission.

5.6 The reflector and alignment device shown in Figures 2 and 3 required setting out by theodolite, in the Burnt Hill instance a Wild T2 theodolite was used. The method employed was as follows.

5.7 With the theodolite set up over the trig control point the reflector bearing was laid off using three other visible trig points as reference points. Two wooden pegs were driven in along the bearing as close to the trig as possible and at an interval of four feet between the peg centres. Two other pegs were put into the ground at right angles to the first two to form a four foot square. The tops of the pegs were then brought to the same level. It was then a simple matter

to place the reflector box on top of the pegs ready for the next step which was the attainment of the reflector vertical angle achieved by use of the alignment device.

5.8 Unfortunately 10/10<sup>ths</sup> cloud cover negated our efforts as far as the 11 April overpass was concerned, but valuable lessons were learned for future attempts.

5.9 Our next planned trial of the reflector is 23 June NZ time and already modifications and improvements have been made to the alignment device. The modification will be discussed in the next report.

6.0 The Lands and Survey Remote Sensing Unit is now well established in its role of co-ordinating body for the LANDSAT Programme within the Department. The following report on Antarctic mapping being one of the more recent developments of the Unit.

7.1 Preparations are in progress for the first serious attempt by Lands and Survey Department in applying the LANDSAT imagery to mapping in the Antarctic.

7.2 One of the Department's surveyors has recently returned from the Antarctic where he was engaged on a triangulation programme around the Ross Sea area.

7.3 His knowledge of the area plus his professional expertise are proving invaluable in the pinpointing of ground control on the imagery.

7.4 At the same time a senior cartographic draughtsman with considerable experience in Antarctic mapping is rarin' to go on the project.

7.5 Although the approach to the exercise has not been finalised, the enthusiasm for the project is such that this should prove to be a valuable and exciting project.

7.6 The mapping scale for this venture will be 1:250,000.

8.0 In conclusion, thanks are again offered to the DSIR Remote Sensing team for their first class service, assistance and valuable advice.

8.1 We are progressing, albeit slowly. As we improve our methods so the future of satellite imagery in mapping looks brighter. To date, we have had nothing but enthusiasm for the project and that coupled with the technical expertise so apparent within the Lands and Survey Department, bode well for the future.

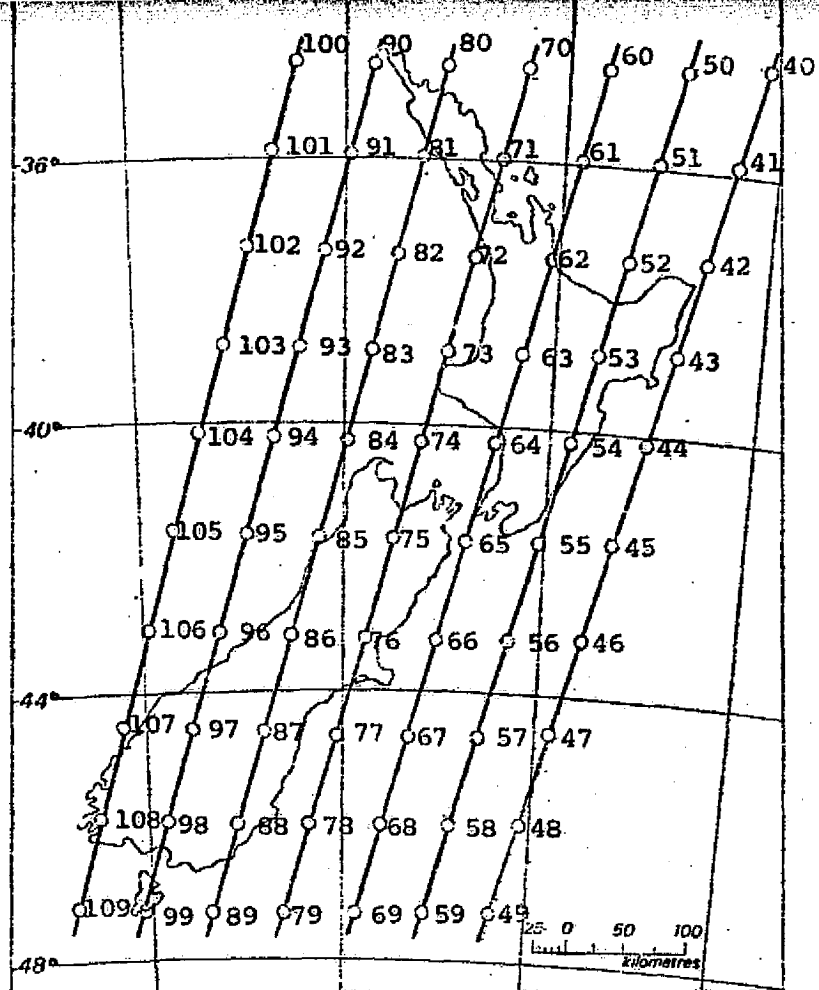
# LANDSAT 2

Scenes received at  
Lands and Survey Dept.  
as at June 1<sup>st</sup> 1976

Line represents Satellite  
track.

Area covered by one scene.  
o represents scene  
centre.

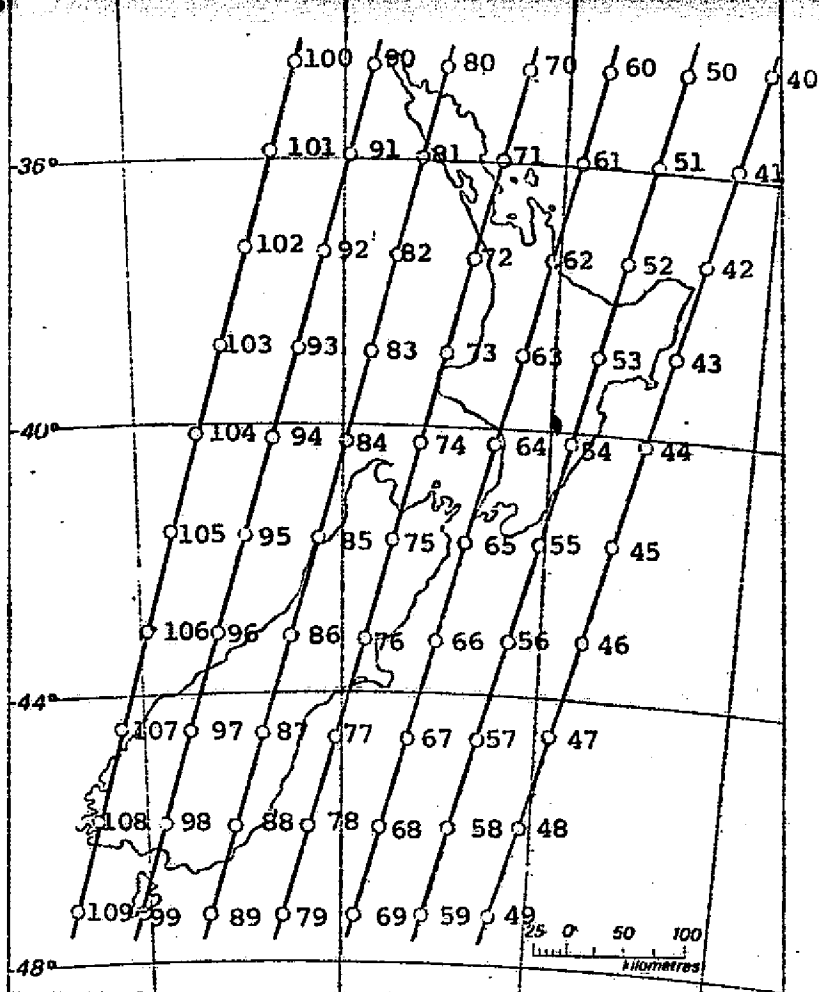
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MAP INDEX No	ID Number		G.M.T. Date	SCENE CENTRE COORDS				LOCATION	SEQUENTIAL ID No
				S		E			
76	2192	21265	2. 8.75	43	05	172	29	Darfield	0013
77	2192	21272	2. 8.75	44	30	171	57	Timaru	0012
71	2264	21235	13.10.75	35	53	174	55	Whangarei	0016
74	2264	21251	13.10.75	40	09	173	30	Farewell Spit	0014
87	2265	21321	14.10.75	44	26	170	30	Benmore	0004
88	2265	21323	14.10.75	45	50	169	57	Dunedin	0005
62	2281	21182	30.10.75	37	21	175	54	Coromandel	0006
63	2281	21185	30.10.75	38	46	175	25	Taupo	0008
65	2281	21194	30.10.75	41	38	174	24	Cook Strait	0015
75	2282	21252	31.10.75	41	36	172	58	Nelson	0017
76	2282	21254	31.10.75	43	02	172	27	Darfield	0007
64	2299	21190	17.11.75	40	14	174	53	Wanganui	0002
65	2299	21192	17.11.75	41	39	174	23	Cook Strait	0003
55	2334	21132	22.12.75	41	33	175	46	Cape Palliser	0001
64	2335	21183	23.12.75	40	06	174	52	Wanganui	0011
65	2335	21190	23.12.75	41	31	174	21	Cook Strait	0010
66	2335	21192	23.12.75	42	56	173	50	Kaikoura	0009
53	2334	21123	22.12.75	38	43	176	45	Kiangaroa	0018
74	2390	21233	16.02.76	40	11	173	21	Farewell Spit	0019
73	2390	21231	16.02.76	38	46	173	50	New Plymouth	0020
63	2389	21172	15.02.76	38	44	175	16	Taumarunui	0021
72	2390	21224	16.02.76	37	20	174	19	Auckland	0022
62	2389	21170	15.02.76	37	19	175	44	Coromandel	0023
61	2389	21163	15.02.76	35	54	176	11	Great Barrier Is.	0024
76	2390	21242	16.02.76	43	02	172	18	Darfield	0025
75	2390	21240	16.02.76	41	37	172	50	Nelson	0026

**Scenes received at  
Lands and Survey Dept.  
as at June 1<sup>st</sup> 1976**

**Area covered by one scene.**  
o represents scene  
centre.

Sheet 2

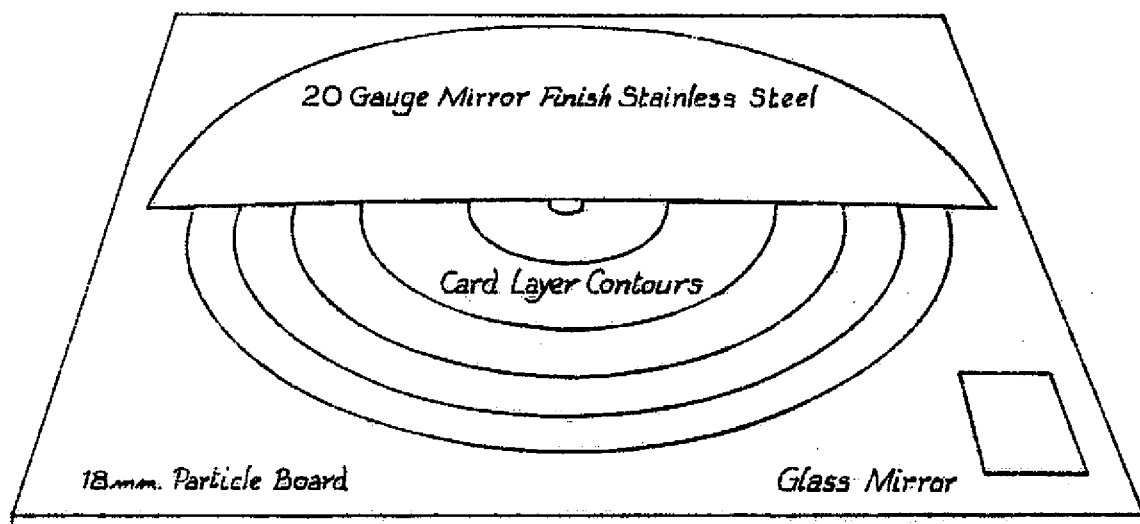


FIG. 2

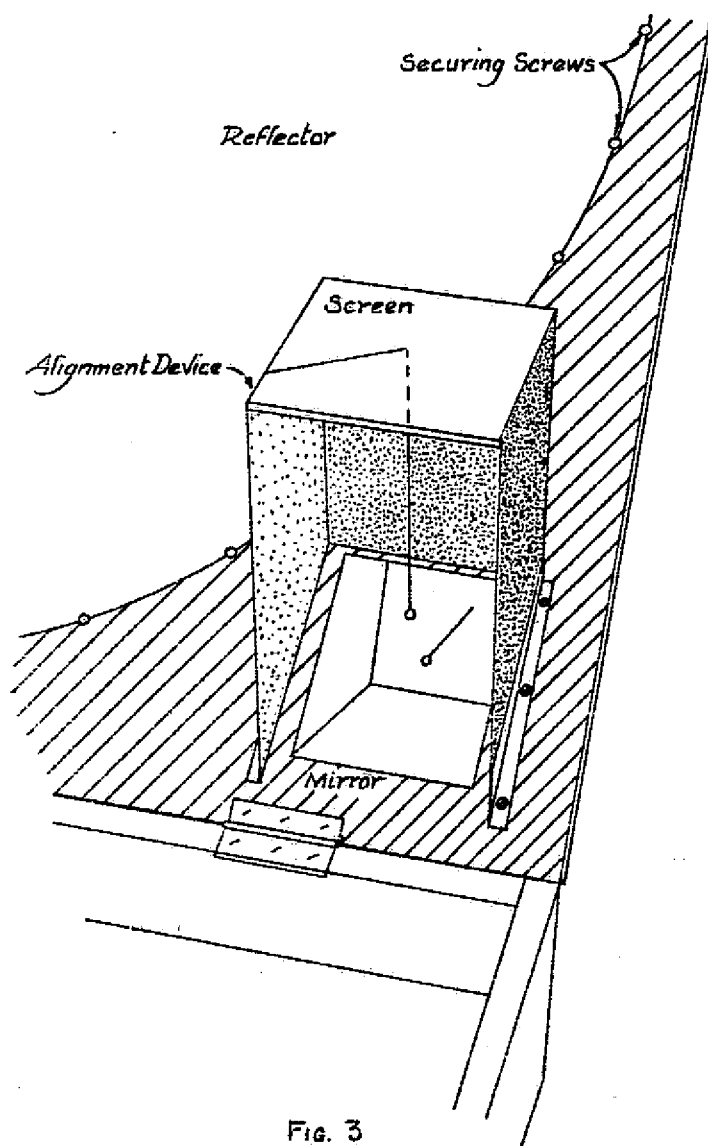
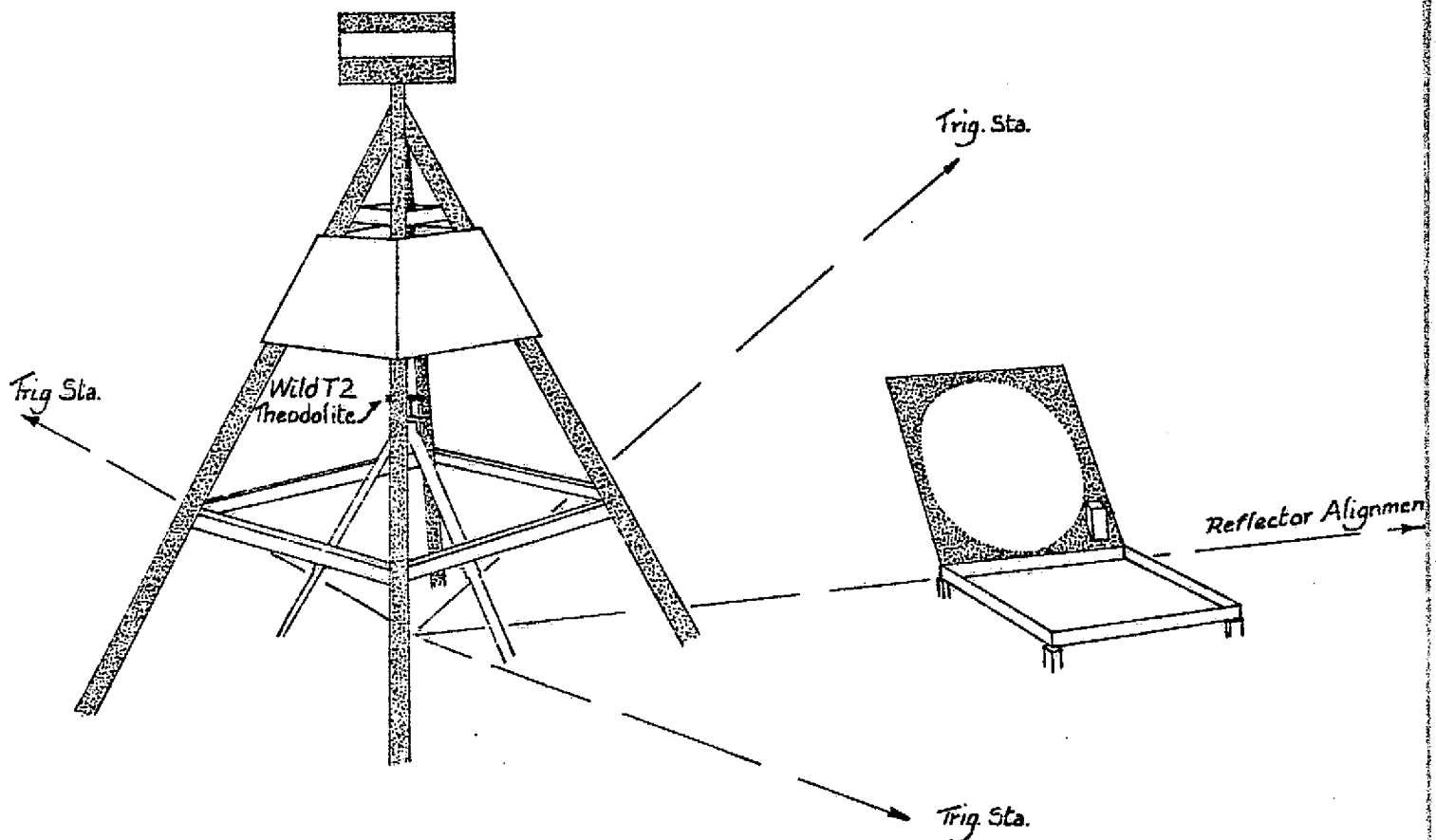


FIG. 3

Burnt Hill Trig. & Reflector Setup  
On April 11 1976

Lat.  $43^{\circ} 22' 52.4642''$   
Long.  $172^{\circ} 08' 12.1663''$   
Ht. A.S.L. 1208 ft.





## PART III

## INDIGENOUS FOREST ASSESSMENT

**Investigation No.:** 2823B

**Co-Investigator:** Mr Michael G. McGreevy

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**Author:** Michael G. McGreevy

F.R.I. is exploring the use of LANDSAT images for assessing forest species, composition, volume, and condition. Condition, which includes damage caused by disease, insects or man, affects both volume and composition. Three major problems are currently being studied; they include: an assessment of the indigenous forest resource, an assessment of wind damaged Pinus spp. and a disease assessment of Pinus radiata infected by Dothistroma pini. Of major importance is the assessment of Pinus radiata as it is the most common commercially planted tree in New Zealand. Of secondary importance is the gathering of information on the condition of the indigenous resource to provide a basis for monitoring its development in the face of growing industrial and agricultural development in New Zealand. Thirdly, the formulation of a system for assessing storm damage would be of value in future situations of widespread damage, and may be useful currently in assessing decay in damaged timber.

#### Topic 1. Indigenous assessment

The imagery received thus far has been plotted on existing ecological survey maps. Approximately 80% of the indigenous forest resource is visible on these images. Attempts to visually distinguish forest types and maturity classes has been difficult. In future, much more reliance will be placed on digitally enhanced images for determining the spectral signatures of indigenous forest species types and volume classes. The signatures obtained will probably require correction for solar elevation and topographic relief. Four sites which exist on CCT's of the Canterbury Plains will be investigated with the aid of enhancements made by M. McDonnell of DSIR, to ascertain the effect of changing topography and aspect on the signature of Beech. Also, any differences among the signatures of several Beech species and a small area of Podocarps which occur in the areas studied, should be defined. The enhancements requested from DSIR should be received and evaluated during the next reporting period. In the absence of CCT's, which seem to suffer long delays between request and receipt, density scans will be performed on 70 mm photographic products to attempt to identify the various forest types of interest.

The draughting section of F.R.I. is currently relocating volumetric plot information on existing ecological survey maps. Although this information is dated, it should still be basically correct due to the near static development of much of the native forest resource. More current volumetric plot information is being tabulated by F.R.I. in co-operation with individual conservancy offices. This task should be completed within the next reporting period and will provide the basis for volumetric correlation with LANDSAT signatures.

## Topic 2. Windthrow in Canterbury Area

Digital enhancement of two CCT's which include Eyrewell Forest illustrate that relatively small areas (less than 6 Ha) of windthrow on pine plantations can be distinguished. The differences are more pronounced on images taken 3 months after the blowdown than on images taken 2 days after, probably due to changes in the foliar condition of damaged trees. Several test points have been established to determine the rate of decay of timber at these points. A comparison of the signature of the timber on current CCT's and future CCT's will be compared with decay rate. Where enhanced signatures have changed differently with time from one location to another, field assessment of the state of decay of the timber at these locations will be made. The assumption of constant decay rate through time will be made. However, if this assumption is invalid, serious discrepancies between the measured state of windthrown timber at various locations and its condition at the actual time of imaging could occur. This may mask real correlations between changes in timber condition and changing spectral signatures. A real time data acquisition system would be invaluable in this instance.

## Assessment of Dothistroma pini in Kaingaroa Forest.

Field work which has involved the sampling of 500 trees by increment boring has been completed. Ten photos from which increment cores have been taken have been measured on LANDSAT-compatible multispectral photography (scale 1:7000) using a colour isodensitometer. Individual compartment Forest Biology Observer Reports on the compartment which contain these field plots and those covered by October 1975

LANDSAT images have been compiled. Silvicultural records on these compartments are also being compiled to give additional information related to canopy coverage and depth in compartments of interest. This information is presently being compared to determine if statistical correlations exist between growth and disease level and/or photographic plot density. A distinct lack of visual information over these forestry sites is forcing a heavy reliance on CCT's for making valid comparisons of irradiance levels within the forest areas. Although we are planning to utilize micro-densitometer measurements of photographic products, we believe that, due to processing, much relevant information is lost.

Dothistroma disease level is most evident during June, July and August. An intensive field measurement of 10 compartments is being undertaken this year. During August 1976, 100 points per compartment with 6 trees sampled for size, growth and disease level at each point, will be compared with density measurements taken on colour reversal photographs at a scale of 1:25,000. Preliminary results indicate that LANDSAT imagery over this area could be very useful for assessing disease level on a compartmental basis. If LANDSAT imagery is available between now and October this year, we will include both digital and photographic assessments of this imagery in our analysis. Final preparations for this project are being made.

A final assessment of our position at this time is that until total cover of New Zealand's indigenous forest resource is obtained, no initial sample for assessing this resource can be allocated. Attempts are being made to define by spectral signatures forest phenomena including species type, volume level, wind damage, decay rate, and disease level in relation to growth. The definition of these phenomena is hindered by processing techniques which render forest scene on positive photography a dense black in which much information is lost. Although digital (CCT) information alleviates these problems, delays in obtaining tapes covering the required forested areas are greatly hindering progress on our project.

17. 3-5a  
PART IV

SEISMOTECTONIC, STRUCTURAL, VOLCANOLOGIC  
AND GEOMORPHIC STUDY OF NEW ZEALAND.

Investigation No. 2823A

Co-Investigator: Dr Richard P. Suggate

Agency: N.Z. Geological Survey

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Mr Gerald G. Lensen

GENERAL

Images have been distributed to our district offices to make use of specialised local knowledge; evaluation is in progress and results are still awaited.

Similarly images were made available to our Earth Deformation Studies Section which has reported some encouraging results listed below.

The lack of coverage discussed in the previous report is again stressed below.

ACTIVE FAULTING IN MARLBOROUGH

Enhancement of linear features through using channel 4 (negative) together with channel 7 (positive) in the colour additive viewer was achieved with remarkable success. An example of such a print and the analysis of that print are attached.

While many major active faults in the area (Marlborough) have been mapped both from air photographs and in the field, the Clarence Fault did not show up on air photographs.

Recent field work on this fault showed its surface features to be subtle and in many places to be almost non-existent. However, on the attached print (Ch4 negative plus Ch7 positive) this fault stands out clearly as does the Fowler's Fault which has been mapped only in part.

It is thought that the moisture content in the crushed rock within the shear zone is considerably higher than that in the adjacent relatively unsheared greywacke. The area under discussion is thinly vegetated by tussock and grass with rock at or near the surface. The combination of Ch7 - positive (which differentiates moisture contents in soils) and Ch4 - negative (which penetrates water) has resulted in a distinct hue in the colour additive viewer.

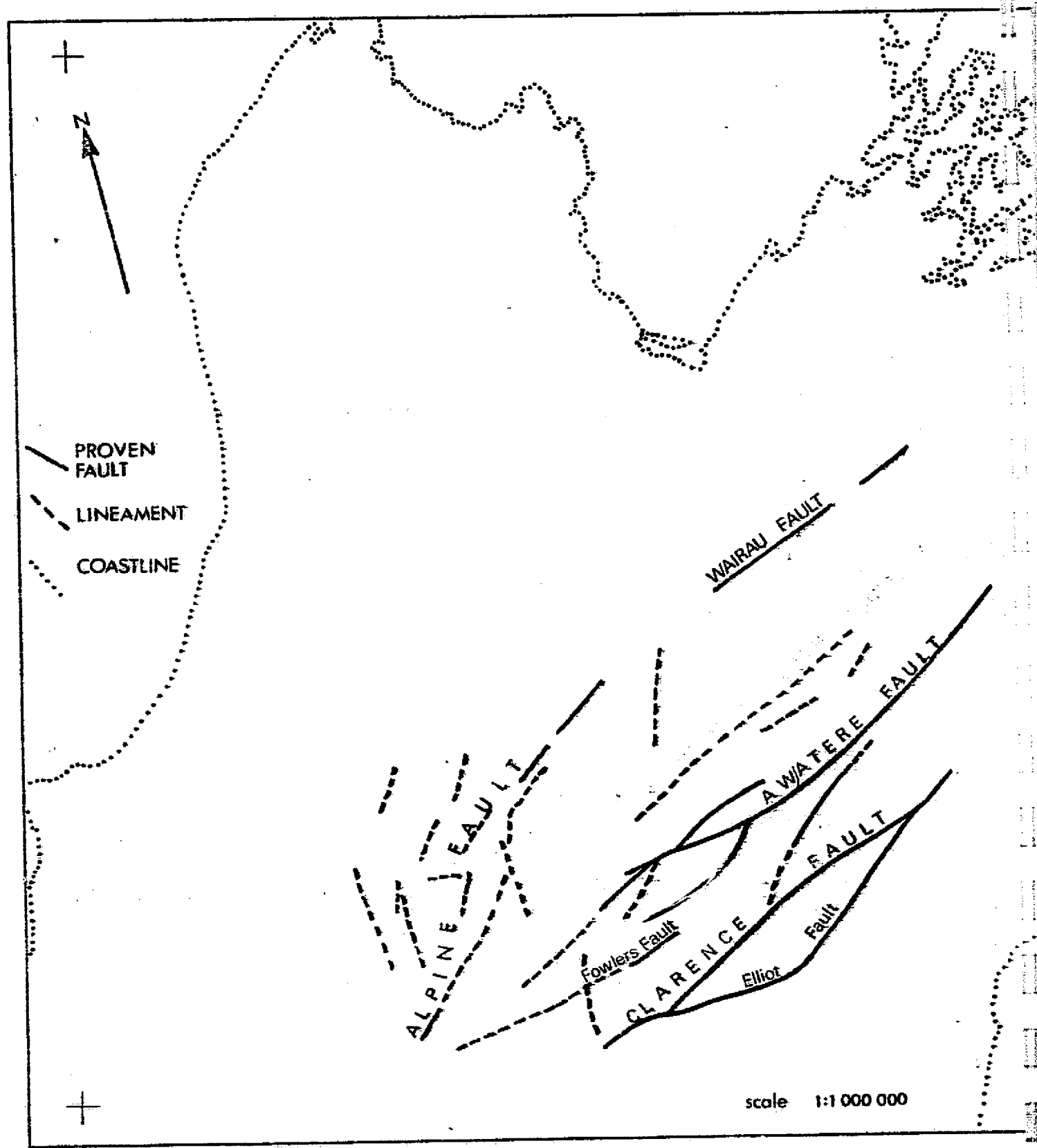
As a result of this investigation the location of the Fowler's Fault has been extended in both directions, while gaps along the Elliott Fault have been filled.

Other linear features hitherto unsuspected have become apparent and ground checks are planned for this coming summer. In particular the long straight lineament between the Awatere and Wairau Faults may prove to be of particular tectonic significance.

#### LITHOLOGIC INTERPRETATION

Lithologic mapping in those areas of New Zealand that are poorly known, using LANDSAT imagery, is considerably hindered by seasonal snow coverage and by vegetation or non-uniform vegetation.

As yet no cloud and snow free images are available in areas of sparse vegetation to provide these optimum conditions. Coverage in summer time (Jan-Feb-March) of the Southern Alps of New Zealand could not only provide the cloud - snow and vegetation-free terrain - but also a relatively unmapped area from which lithologic information obtained by LANDSAT imagery studies would be most valuable. The isodensitometer would seem to be the most promising way of examining the images to detect major lithologic units.





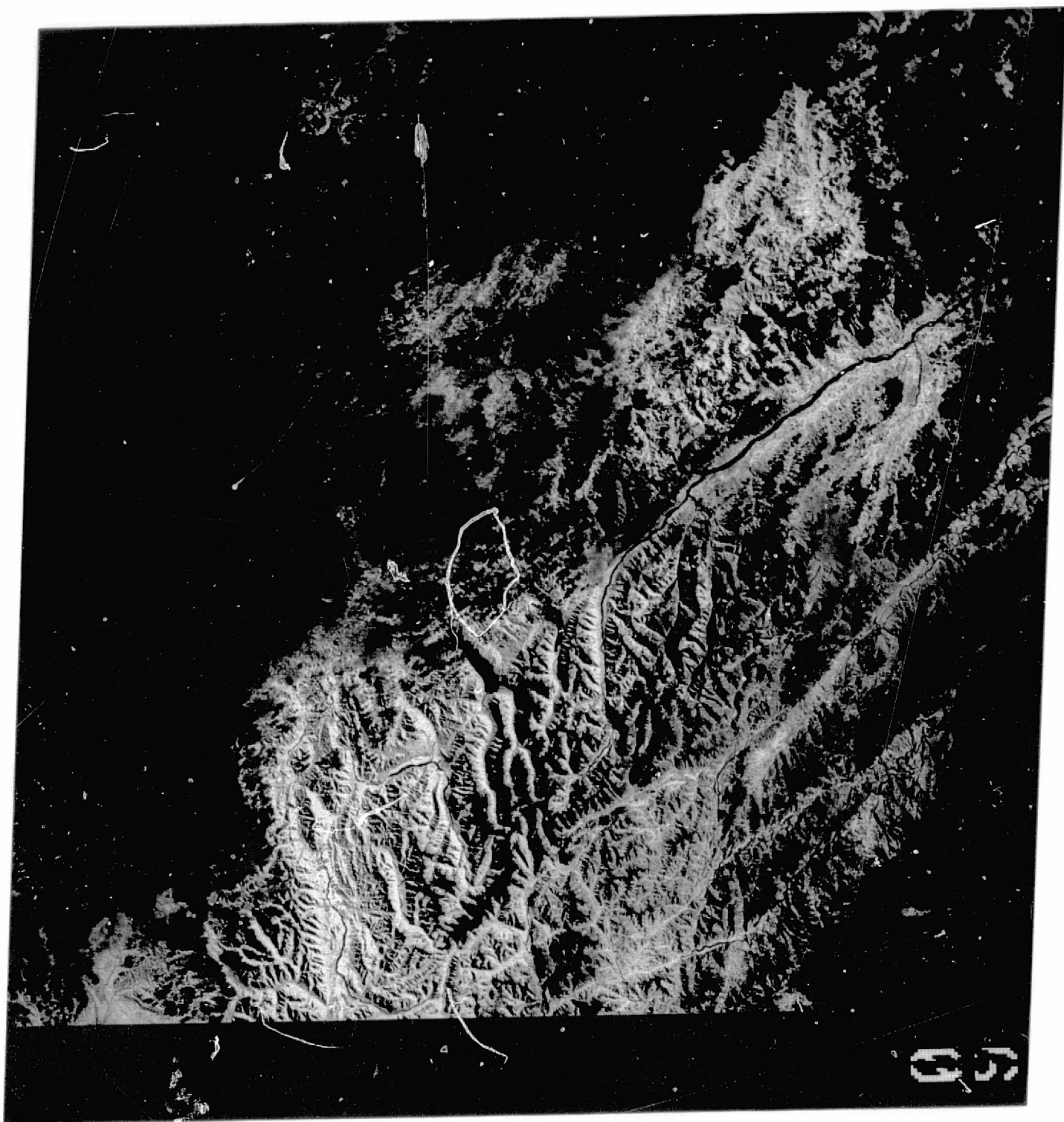


Figure 1 - Colour combination of positive transparency (MSS 7) and negative transparency (MSS 4) of the north end of the S.I. (16 FEB 1976). Outline map (opposite) shows identifiable fault lines.